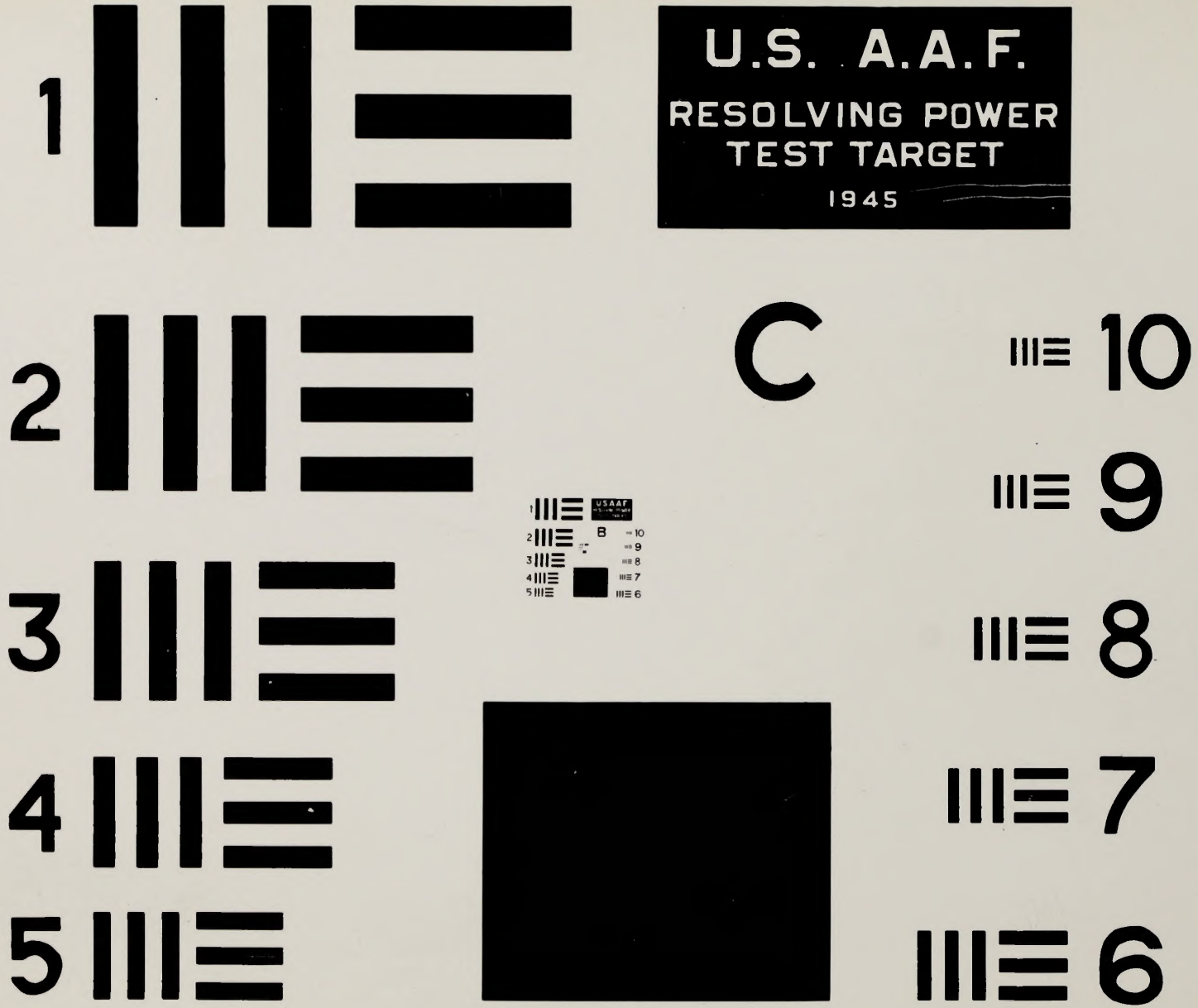
Photographic Print Resolution

by

Arthur Fentin


1
U.S. A.A.F.
RESOLVING POWER
TEST TARGET
1945
2
C
10
9
3
8
4
7
5
6

BOSTON UNIVERSITY
GRADUATE SCHOOL
Thesis

PHOTOGRAPHIC PRINT RESOLUTION

by

Arthur Fentin
(A.B. Boston University, 1946)

submitted in partial fulfilment of the
requirements for the degree of
Master of Arts

1947

BOSTON UNIVERSITY
GRADUATE SCHOOL
Thesis

PHOTOGRAPHIC PRINT RESOLUTION

by

Arthur Fentin
(A.B., Boston University, 1946)
Submitted in partial fulfillment of the
requirements for the degree of
Master of Arts

1947

Approved
by

First Reader Duncan E. Macdonald
Professor of Physics

Second Reader Royal K. Fuyat
Professor of Physics

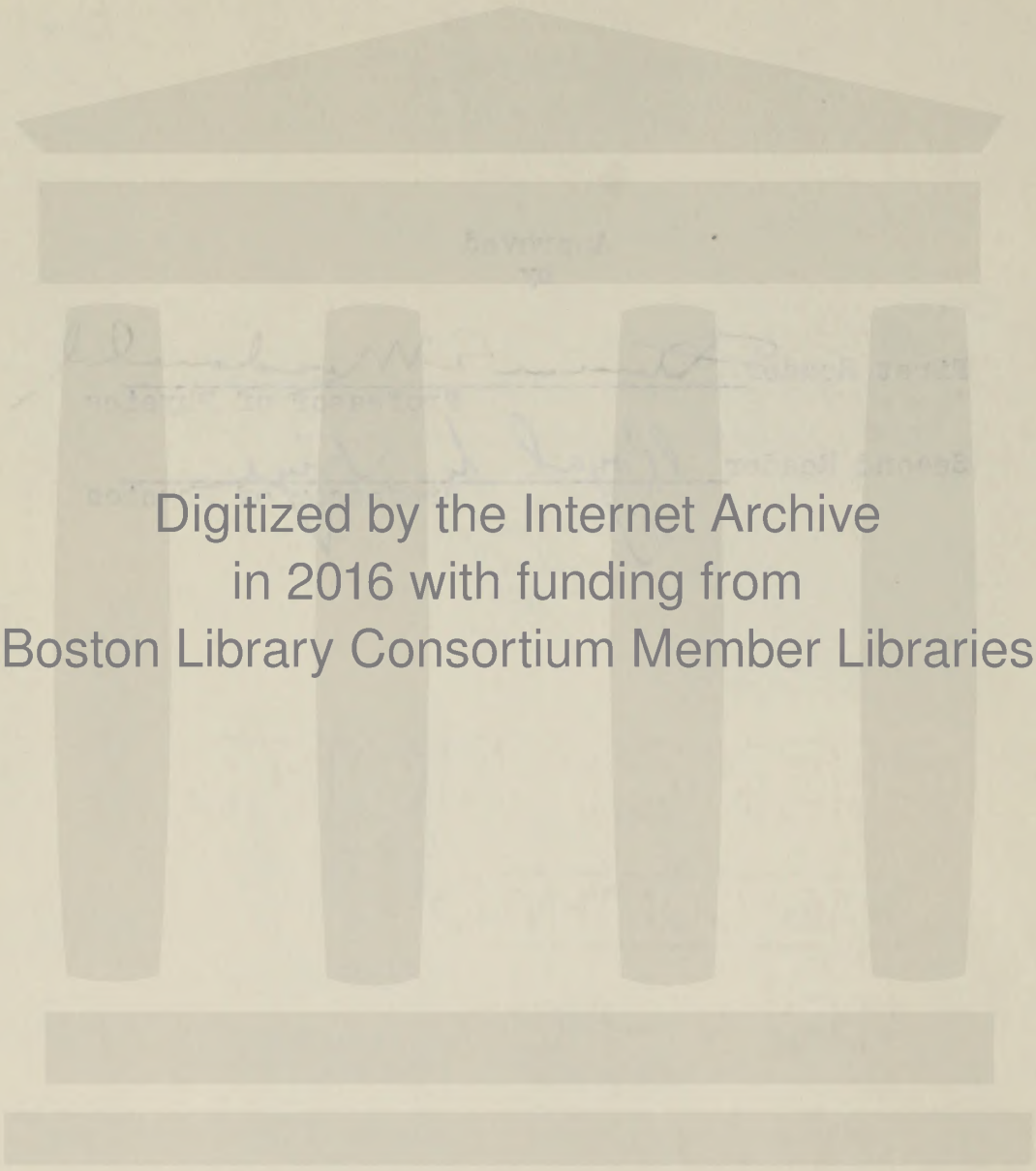


TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS

(Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

FOREWORD

The author is indebted to the Boston University Optical Research Laboratory, on behalf of whom this research was undertaken, for permission to submit this thesis for partial fulfilment of the requirements for the degree of Master of Arts in Physics at Boston University.

The author wishes to acknowledge his indebtedness to his colleagues at the laboratory for their invaluable assistance. In particular, thanks are due the analysis section, engineering department, and the photographic department. Special thanks are due Dr. Macdonald for his guidance and many helpful suggestions.

FOREWORD

The author is indebted to the Boston University Optical Research Laboratory, on behalf of whom this research was undertaken, for permission to submit this thesis for partial fulfilment of the requirements for the degree of Master of Arts in Physics at Boston University.

The author wishes to acknowledge his indebtedness to his colleagues at the laboratory for their invaluable assistance. In particular, thanks are due the analysis section, engineering department, and the photographic department. Special thanks are due Dr. Macdonald for his guidance and many helpful suggestions.

INTRODUCTION

A. Statement of the Problem:

Photographic print resolution until recent years, was considered only as the sequence of the photographic process. However, with the increased dependence of military campaigns upon photographic reconnaissance, the need for investigating photographic print resolution, independent of negative resolution, was apparent. A small amount of work was done during the war on the various phases of this problem, but because it was still relegated to a minor role, the results were scattered and inconclusive. This thesis is then an attempt to determine the fundamental problems involved in print resolution.

B. Resolving Power of Photographic Materials:

Photographic resolving power, according to Huse[1] is defined as the distance by which two minute images, lying adjacent to one another, are just separated in the developed plate. In the judgment of the separation it is assumed that the image is so viewed as to be well within the resolving power of the eye, and also not magnified to an extent that will make the individual silver grains more apparent than their groupings.

The resolving power is a function of the following quantities: The turbidity, gamma (i.e. the slope of the straight-line portion of the D log E curve), visual resolution and lightness ratio of the test-object.

---

1. Huse, K., "Photographic Resolving Power", J.O.S.A. p.119, 1917

INTRODUCTION

A. Statement of the Problem:

Photographic print resolution until recent years was considered only as the sequence of the photographic process. However, with the increased dependence of military campaigns upon photographic reconnaissance, the need for investigating photographic print resolution, independent of negative resolution, was apparent. A small amount of work was done during the war on the various phases of this problem, but because it was still relegated to a minor role, the results were scattered and inconclusive. This thesis is then an attempt to determine the fundamental problems involved in print resolution.

B. Resolving Power of Photographic Materials:

Photographic resolving power, according to Huse[1] is defined as the distance by which two minute images, lying adjacent to one another, are just separated in the developed plate. In the judgment of the separation it is assumed that the image is so viewed as to be well within the resolving power of the eye, and also not magnified to an extent that will make the individual silver grains more apparent than their groupings.

The resolving power is a function of the following quantities: The turbidity, gamma (i.e. the slope of the straight-line portion of the D log E curve), visual resolution and lightness ratio of the test-object.

---

1. Huse, K., "Photographic Resolving Power", J.O.S.A. p.119, 1917

Ross[2] attempted to link together the relevent properties and arrived at the formula: $R = \frac{K\gamma}{a+bd^2}$ where R is the resolving power in 1/mm, γ the slope of the characteristic, d the grain diameter, K the scattering constant as derived from the illumination intensity equation, $I = I_o e^{-kt}$, and a+b empirical constants. This formula was not satisfactory, since graininess and not grain size was involved. Frieser and Links[3] did succeed in proving that the just discernible density difference between light and dark lines in the negative depended upon the grain size of the negative emulsion, but even with this evidence the determination of the resolving power as a function of the properties of the emulsion could not be established with any precision. A mass of information has been collected relating resolving power to exposure, wave-length, time of development, constitution of developer, type of test object, contrast, and emulsion properties.

C. Determination of Processing Procedure:

By reason of the problem, a processing system had to be set-up which could be adapted for ordinary and large scale production of prints. With this and the recommended processing periods of time in mind, the following system was set-up.

Developer: Eastman Kodak D-72	-- 1 min. at 68°F
Short Stop Bath: Kodak SB-1	-- 30 sec.
Hypo: - - - - - - - - - - - -	-- 15 min.
Wash: - - - - - - - - - - - -	-- 1 hr. cont. agitation
Dry: - - - - - - - - - - - -	-- Pako drier at 150°F (total time 8½ min)

---

2. Ross, "Physics of the Developed Photographic Image" Astro. Phys. J. 52, p. 201, -1920

3. Frieser & Links, "Zeits. f. Wiss. Phot. 37, p.19, 1938

c. Determination of Processing Procedure:

By reason of the problem, a processing system had to be set-up which could be adapted for ordinary and large scale production of prints. With this and the recommended processing periods of time in mind, the following system was set-up.

Developer: Eastman Kodak D-72 -- 1 min. at 68°F
Short Stop Bath: Kodak SB-1 -- 30 sec.
Hypo: - - - - - - - - - - - - - - -- 15 min.
Wash: - - - - - - - - - - - - - - -- 1 hr. cont. agitation
Dry: - - - - - - - - - - - - - - -- Pako drier at 150°F
(total time 3½ min)

---

2. Ross, "Physics of the Developed Photographic Image" Astro. Phys. J. 52, p. 201, -1920

3. Frieser & Links, "Zeits. f. Wiss. Phot. 37, p.19, 1938

The safelights employed with each paper used was as recommended by the manufacturer.

D. Determination of Variables and Results:

Since the number of variables were too numerous to be evaluated, it was decided that this work would be limited to the basic variables.

The first problem in this connection was to determine the best type of light source. Four types of printers, all involving different principles were employed: the Army Printers A-11 and A-14, both approximating 100% diffuse light; the Eastman Kodak Studio Printer, used without diffusing glass, giving fair point source illumination; the Edgerton Flash Unit with a printing frame, yielding highly directional light; and a laboratory printer, yielding incident light of a maximum angle of 0.31^{o}.

The experimental results show that the closer we approach either parallel or point source illumination, the higher the value of resolution.

The second problem, logically, is a comparison of the maximum resolution of chloride and bromide papers. This was done in all contrasts on glossy and semi matte. In addition, a multicontrast glossy paper was used.

Employed in the tests were Azo and Velox Contact Printing Papers, Kodabromide Enlarging Paper, and Varigam Multicontrast Enlarging and Printing Paper. The results of the tests show that of all the papers used, Varigam, when used without a filter, gave the best results. In the comparison between semi-matte and glossy papers, it was found that semi-matte gave a higher average maximum resolution. The Bromide paper was

D. Determination of Variables and Results:

Since the number of variables were too numerous to be evaluated, it was decided that this work would be limited to the basic variables.

The first problem in this connection was to determine the best type of light source. Four types of printers, all involving different principles were employed: the Army Printers A-11 and A-14, both approximating 1000 diffuse lights; the Eastman Kodak Studio Printer, used without diffusing glass, giving fair point source illumination; the Edgerton Flash Unit with a printing frame, yielding highly directional light; and a laboratory printer, yielding incident light of a maximum angle of 0.31°.

The experimental results show that the closer we approach either parallel or point source illumination, the higher the value of resolution.

The second problem, logically, is a comparison of the maximum resolution of chlorite and bromide papers. This was done in all contrasts on glossy and semi matte. In addition, a multicontrast glossy paper was used.

Employed in the tests were Azo and Velox Contact Printing Papers, Kodabromide Enlarging Paper, and Varigam Multicontrast Enlarging and Printing Paper. The results of the tests show that of all the papers used, Varigam, when used without a filter, gave the best results. In the comparison between semi-matte and glossy papers, it was found that semi-matte gave a higher average maximum resolution. The Bromide paper was

found to record a higher resolution than the chloride in all cases, while Grade 2 Paper was found to give the highest average resolution of all the grades of paper.

The third and last of the basic problems to be considered was the effect of pressure on photographic print resolution. A set of conditions were taken from the tests of the previous problem at random and prints were made with increasing pressure. The resulting curve proved to be asymptotic leveling off at a maximum value of 80 l/mm at a pressure of 5lbs/sq.in.

By the use of the original constants and the incorporation of these experimental results, the way is now cleared for further detailed study of the problem of photographic print resolution.

CHAPTER I

A. Statement of the Problem:

1. The effect of Source on the Resolution of photographic printing paper.
2. A comparison of the Army A-11 and A-14 contact printers.

B. Experimental Procedure:

1. Materials

a) Test object:

The negative used in this work was a U.S. Army test object of infinite contrast and maximum resolution of 200 l/mm. (See Appendix A)

b) Positive Material:

The positive material used in this test was Azo paper, Grades 0-5, glossy, smooth, white.

2. Processing Procedure for Entire Research

a) Developer used was D-72 diluted one part stock to two parts water.

1. The first four prints developed in the fresh solution were discarded.
2. Only fifty prints were developed in each quantity of developer.
3. Each print was agitated throughout the period of development.
4. Each print was developed for one minute at 67-71° F.
5. All prints on Azo paper were developed under a series 0-0 Wratten safelight.
6. All prints on Bromide paper were developed under a series OA Wratten safelight.
7. All prints on Varigam paper were developed under a series 3 Wratten safelight.

CHAPTER I

A. Statement of the Problem:

1. The effect of Source on the Resolution of photographic printing paper.
2. A comparison of the Army A-II and A-IA contact printers.

B. Experimental Procedure:

1. Materials

a) Test object:

The negative used in this work was a U.S. Army test object of infinite contrast and maximum resolution of 200 l/mm. (See Appendix A)

b) Positive Material:

The positive material used in this test was Azo paper, Grades 0-5, glossy, smooth, white.

2. Processing Procedure for Matte Paper

a) Developer used was D-72 diluted one part stock to two parts water.

1. The first four prints developed in the fresh solution were discarded.
2. Only fifty prints were developed in each quantity of developer.
3. Each print was agitated throughout the period of development.
4. Each print was developed for one minute at 67-71° F.
5. All prints on Azo paper were developed under a series 0-0 Wratten safelight.
6. All prints on Brovira paper were developed under a series OA Wratten safelight.
7. All prints on Varigam paper were developed under a series 3 Wratten safelight.

b) All prints were immersed in short stop bath Kodak SB-1 for thirty seconds.

c) All prints were fixed in hypo for 15 minutes.

d) All prints were washed for one hour with continuous agitation from Kodak tray syphon.

e) All prints dried on Pako Drier without any gloss treatment at 150°F over time period of 8½ min.

f) All matte prints dried on Pako Drier without gloss treatment, face down at 200°F over time period of 8½ min.

3. Discussion of Experiments

a) Army A-14 Printer:

1. Description - The printer handles negatives up to 9x18 inches and is equipped with Argon lights. The light is spread out evenly through a piece of frosted glass. A pneumatic rubber bag, which is instrumental in eliminating air pockets, provides uniform contact between the negative material, the sensitized paper and the negative glass. The time of exposure was controlled by a professional-type electronic timer.

2. Prints were made on Azo Paper, glossy, white, smooth, Grades o-5 inclusive.

3. Processing was carried out as outlined.

4. Pressure was considered equal to zero.

b) Army A-11 Printer:

1. Description - The printer handles negatives up to 9x9 inches and is equipped with Argon lights. The light is spread out evenly through a piece of frosted glass. A pneumatic rubber bag, which is instrumental in eliminating air pockets, provides uniform contact between the negative material, the sensitized paper and the frosted glass. The time of exposure was controlled by a professional type electronic timer.


TIME
PUSH
PROFESSIONAL

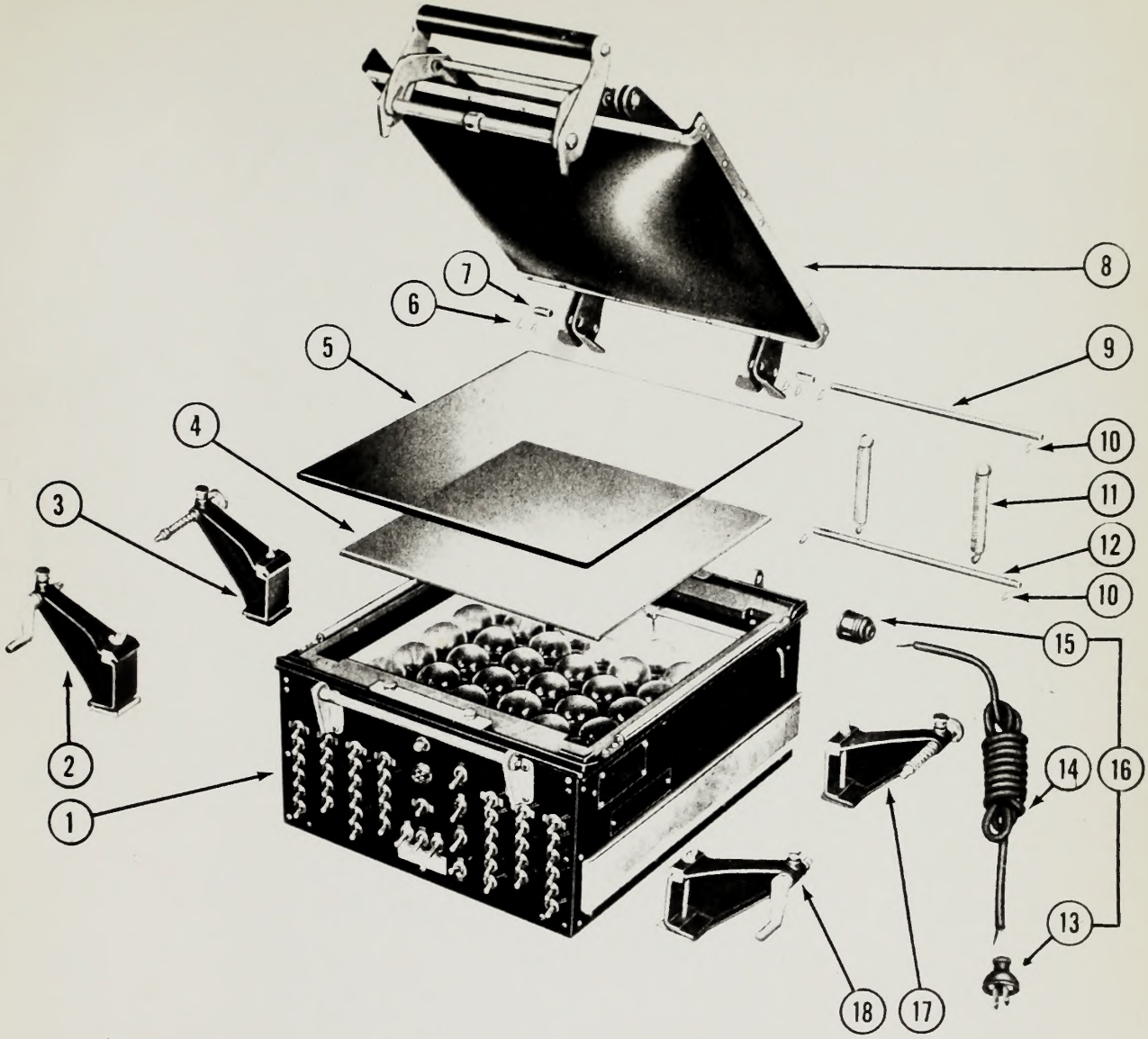


Figure 8—Exploded View—Main Assemblies

KEY TO FIGURE 8

Index No.	*Name*	*Index No.*	*Name*
1	Box assembly	10	Clip
2	Crank bracket assembly	11	Rear tension spring
3	Spool bracket assembly	12	Rear spring support bottom rod
4	Diffusion glass	13	Electric plug
5	Printing glass	14	Cord
6	Clip	15	2-pole receptacle
7	Rear lid support rod	16	Extension cord assembly
8	Lid assembly	17	Spool bracket assembly
9	Rear spring support top rod	18	Crank bracket assembly

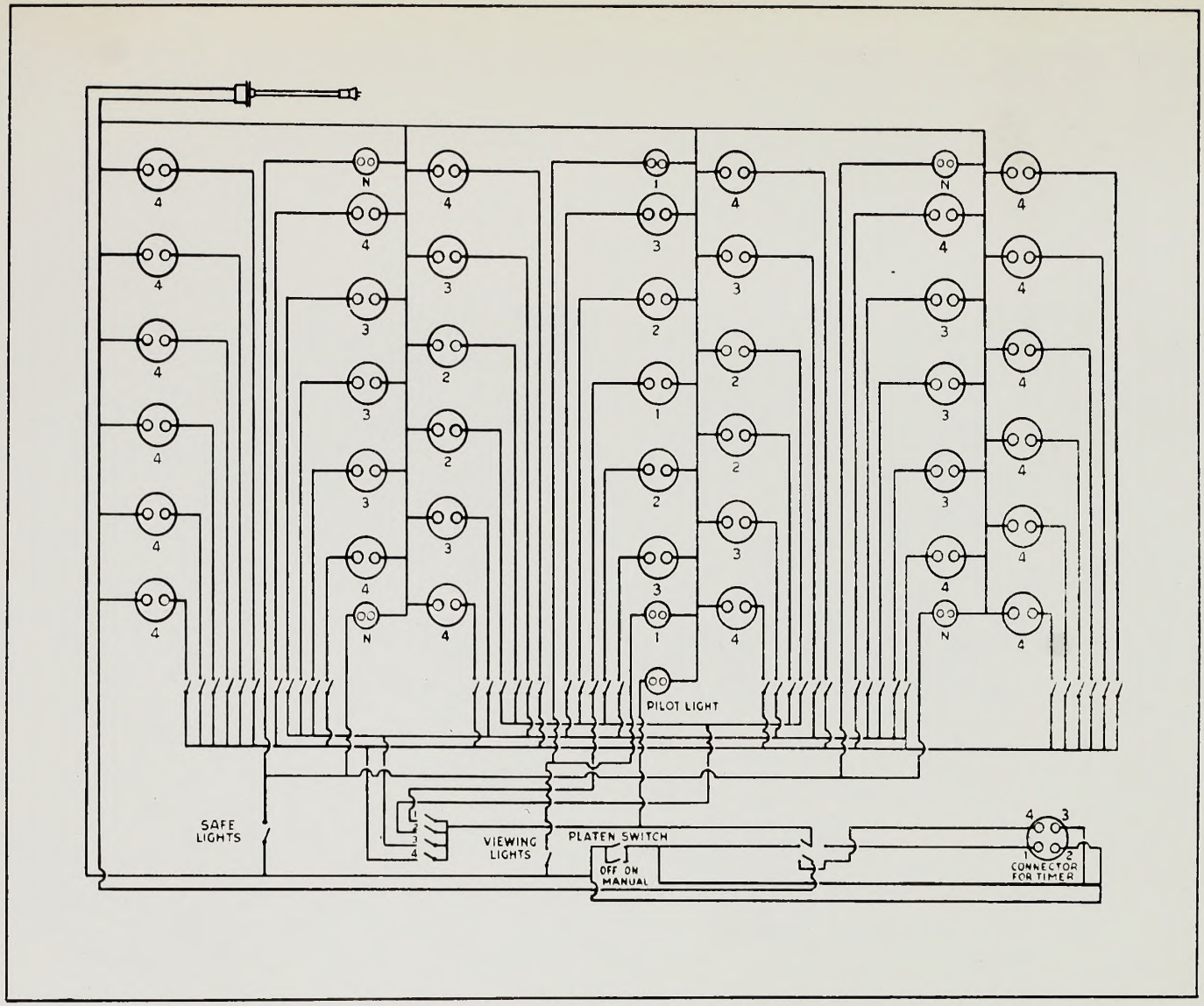
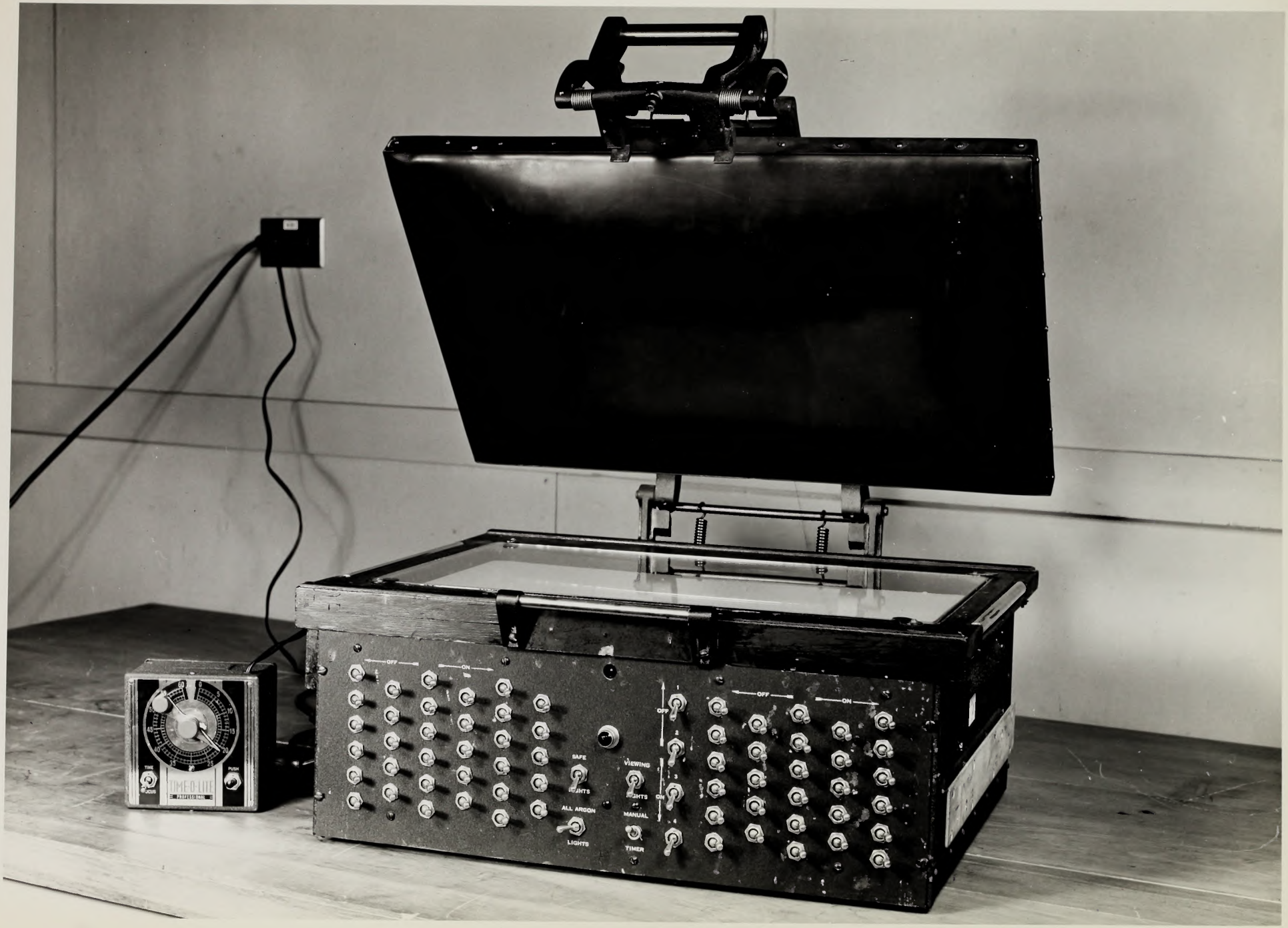


Figure 13—Wiring Diagram

KEY TO FIGURE 13

Index No.	*Name*
1, 2, 3, 4	Argon glow lamps
N	Photographic safe lights
I	Viewing lights


OFF
ON
SAFE
LIGHTS
ALL ARGON
LIGHTS
VIEWING
LIGHTS
MANUAL
TIMER
OFF
ON
TIME-O-LITE

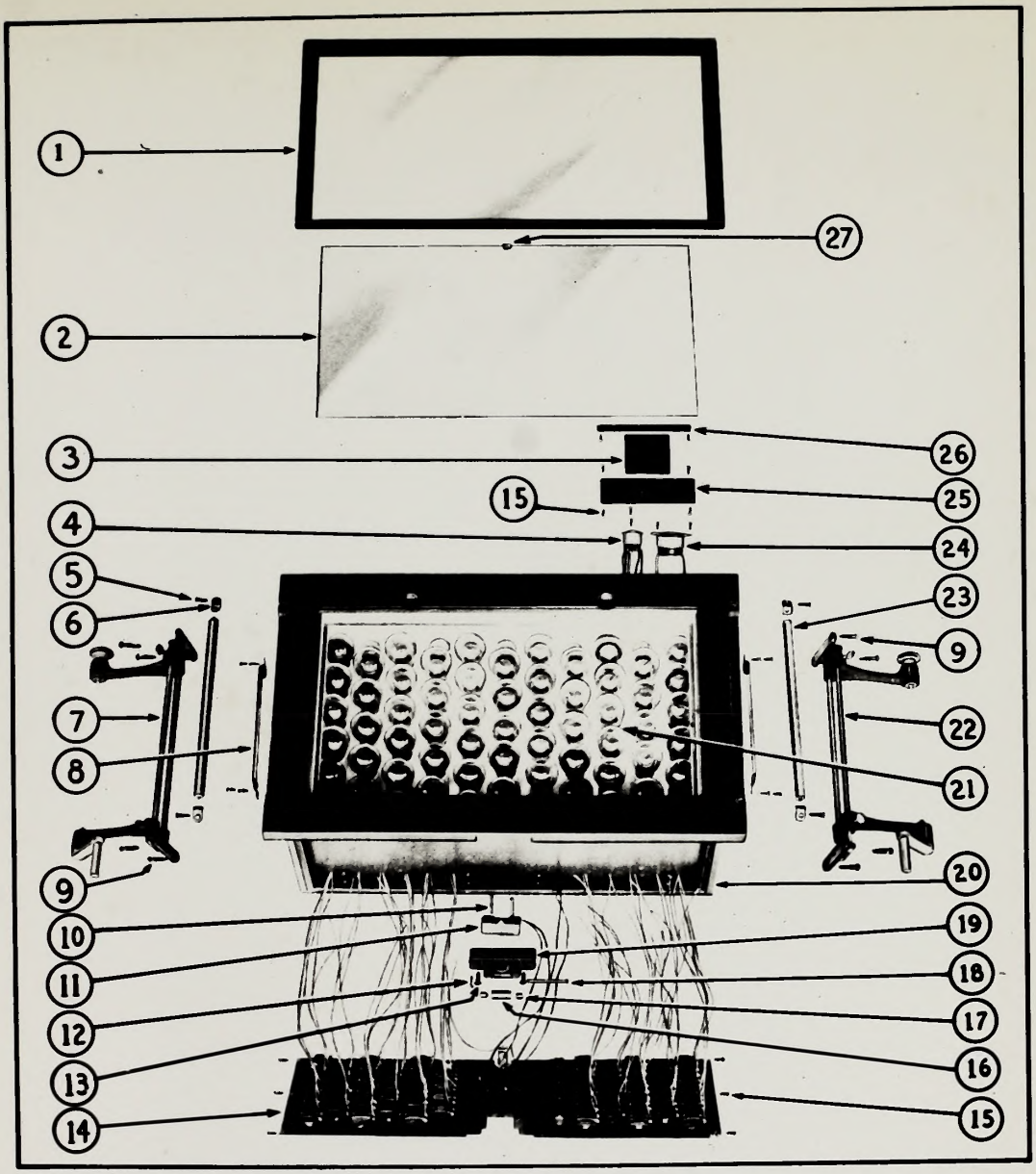


Figure 9—A-11 Printer Without Leverlid and Lid Assembly

KEY TO FIGURE 9

Index No.	Nomenclature
1	Glass—Printing
2	Glass Assembly—Diffusing
3	Shutter
4	Receptacle—Recessed, three-pole, male
5	Screw—Flathead, No. 6x3/4-in.
6	Bearing—Angle
7	Spool Assembly—Bracket, left
8	Cover—Ventilator
9	Screw—Roundhead, No. 10x1-in.
10	Screw—Machine
11	Switch—Micro
12	Pin—Cotter
13	Screw—Roundhead, No. 6x3/4-in.
14	Panel Assembly—Switch
15	Screw—Recessed No. 4x1/2-in.
16	Roller
17	Bearing—Needle
18	Pin—Flathead
19	Casting—Housing
20	Box Assembly—Wood
21	Light Assembly—Base
22	Spool Assembly—Bracket, right roller
23	Roller
24	Receptacle—Recessed, two-pole, male
25	Track—Upper and sign
26	Track—Lower

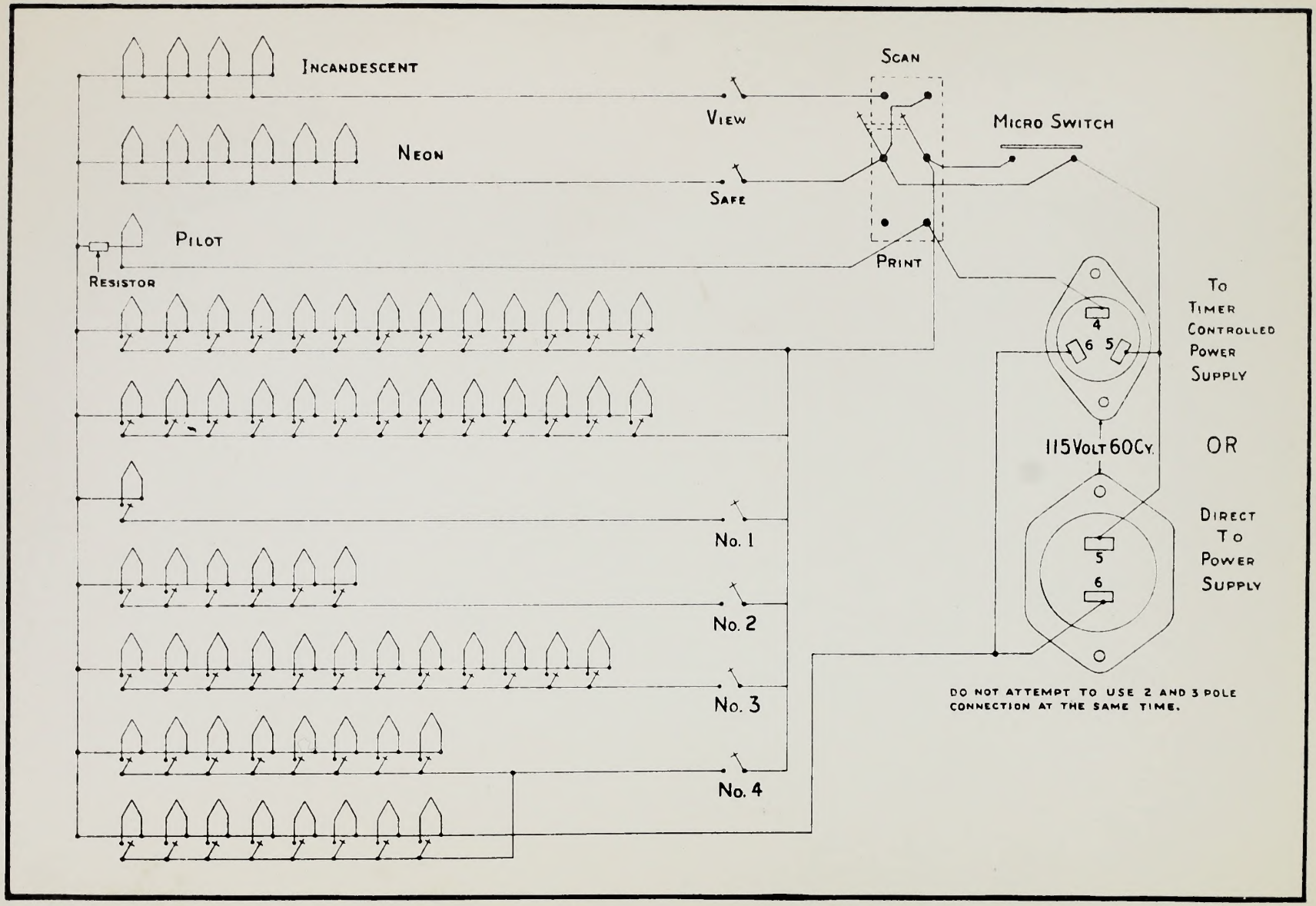


Figure 12—Wiring Diagram for A-11 Printer

2. Prints were made on Azo Paper, glossy, white, smooth, Grades 0-5 inclusive.

3. Processing was carried out as outlined.

4. Pressure was considered equal to zero.

c) Kodak Studio Printer:

1. Description - The printer uses a strong single concentrated light source which is projected to the negative in a narrow cone without diffusion. The light is projected through the negative by reflection from a parabolic mirror. The light source was a 250 watt projection bulb. The pressure plate consists of small rubber pegs molded in a solid sheet of translucent rubber, backed up with heavy cellulose acetate attached to metal plates.

2. Prints were made on Azo Paper, glossy, white, smooth, Grades 0-5 inclusive.

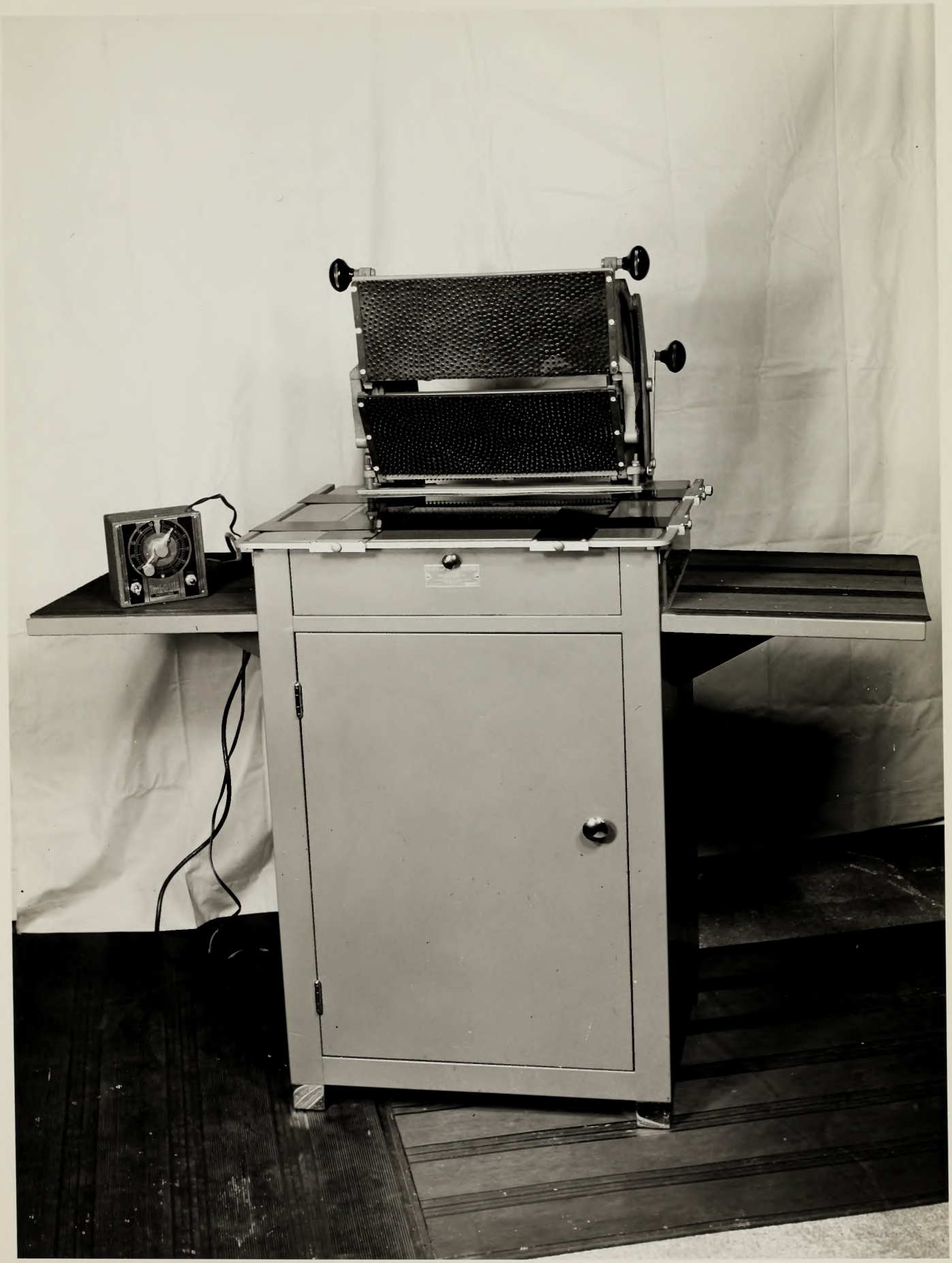
3. Processing was carried out as outlined.

4. Pressure was considered zero, which was facilitated by removing the pressure springs.

d) Laboratory Point Source Printer:

1. Description - The printer consisted of two five foot long rectangles, one of which fitted into the other. The top was covered with a piece of $\frac{1}{4}$" plate glass. A heavy piece of steel was used as the pressure plate with a piece of masonite separating the steel and the positive material to insure even pressure over the entire area. The lower end of the top half was fitted with various apertures to control the amount of light passing through to the negative. The sources used in this setup included: a 300 watt projection bulb; a 100 watt frosted bulb; and the Edgerton flash unit.

2. Prints were made on Azo Paper - glossy, white, smooth, and Kodabromide - glossy, white, smooth.



3. Processing was carried out as outlined.

4. Description of tests.

(a) The first tests were made with the Edgerton flash unit on Azo F-1 printing paper, using a $\frac{1}{4}$" aperture covered with a piece of ground glass. The distance from the pinhole to the negative material was five feet and the distance from the top of the bulb to the pinhole $2\frac{1}{2}$" giving a total distance of five feet 2.5".

(b) In the next set of tests, the aperture was increased to 1" and the ground glass removed. Exposures were made with the Edgerton Flash Unit, 100 watt frosted bulb, and a 300 watt projection bulb on Azo F-1 and F-5 printing paper. The distances from top of source to glass were as follows: Edgerton Unit 5', 2.5"; 100 watt frosted bulb 5', 5.75"; 300 watt projection bulb 5', 3.5".

(c) In the next test the aperture was reduced to 3/32" and exposures of long duration made with the 100 watt frosted bulb on Azo F-1 Printing Paper.

(d) A column of brass five feet long and 9/16" in diameter, painted flat black inside, was then mounted in the upper half of the printer. A 3/32" aperture was used with a 300 watt projection bulb and exposures were made on Kodabromide F-1 enlarging paper.

(e) The aperture was then reduced to .0135" in diameter and exposures were made on Kodabromide F-1 enlarging paper with a 300 watt projection bulb through the five foot collimator.

(f) The aperture was then increased to 3/32" in diameter and exposures were made on Azo F-1 printing paper with a 300 watt projection bulb through the five foot column.

(g) The final tests involved a .0135" aperture with the five foot column. Exposures were made on Kodabromide F-1 enlarging paper with a 300 watt projection bulb.

5. The pressure on the test object and sensitized paper was calculated as follows:

Total weight of steel and masonite = 5.25 lbs.

Total area of test object = (3x4") 12 sq. in.

Calculated pressure per square in. = .4375 per sq. in.

e) Edgerton Flash Unit:

1. Description

(a) Flash Unit Operation: Line voltage of 120 V., A.C., is stepped up to an R.M.S. value of 1650 volts, which is rectified and applied to the discharge condenser, giving a direct voltage of about 2000 V. This voltage is also applied directly across the flash lamp. When the trip switch is thrown, positive voltage is applied to the screen grid of the tube (Strobotron), causing a pulse of cathode current. Cathode voltage rises in a positive direction, discharging the .01 MFD condensor through the spark coil. The intense electric field produced in the gas of the flash lamp by the secondary winding of the coil ionizes the gas, allowing the main discharge condensor to discharge through the flash lamp. The system will then remain inoperative until the main discharge condensor has had time to charge again.

(b) The Flash Lamp: It is a five turn helix of quartz tubing provided with two electrodes and filled with Xenon gas. The source size is approximately 1 and 3/16" by 1 and 5/8".

(c) Characteristics:

Operating volts (DC) = 2000 volts

Maximum capacity at recommended operating voltage = 100 microfarads

5. The pressure on the test object and sensitized paper was calculated as follows:

Total weight of steel and masonite = 5.25 lbs.

Total area of test object = (3x4") 12 sq. in.

Calculated pressure per square in. = .4375 per sq. in.

e) Edgerton Flash Unit:

1. Description

(a) Flash Unit Operation: Line voltage of 120 V., A.C., is stepped up to an R.M.S. value of 1650 volts, which is rectified and applied to the discharge condenser, giving a direct voltage of about 2000 V. This voltage is also applied directly across the flash lamp. When the trip switch is turned, positive voltage is applied to the screen grid of the tube (Ethobiton), causing a pulse of cathode current. Cathode voltage rises in a positive direction, discharging the oil-filled condensor through the spark coil. The intense electric field produced in the gas of the flash lamp by the secondary winding of the coil ionizes the gas, allowing the main discharge condensor to discharge through the flash lamp. The system will then remain inoperative until the main discharge condensor has had time to charge again.

(b) The Flash Lamp: It is a five turn helix of quartz tubing provided with two electrodes and filled with Xenon gas. The source size is approximately 1 and 3/16" by 1 and 5/8".

(c) Characteristics:

Operating volts (DC) = 2000 volts

Maximum capacity at recommended operating voltage = 100 microfarads

Maximum energy input at recommended operating voltage = 200 watt /seconds

Lumen output per flash =8000 lumen - (approx. seconds

2. Prints were made on Azo paper, glossy, white, smooth, Grades 0-5 inclusive.

3. Processing was carried out as outlined.

4. The pressure was calculated as follows: weights were supported on one end of one pressure strap until it just started to pull away from the circular disk holding it down. These weights were then weighed and the value multiplied by two, since each strap acted on two sides of each half of the printing frame. This value was taken as the total pressure because the negative was mounted in only one-half of the printing frame.

Total value of weights = $17\frac{1}{2}$ lbs.

Total pressure on $\frac{1}{2}$ of frame = 35 lbs.

Total area of test object =(3x4) 12 sq. in.

Calculated pressure per sq. inch = 35/12 =2.917 P.S.I.

Maximum energy input at
recommended operating
voltage = 200 watt \seconds

Lumen output per flash =6000 lumen -
approx. seconds)

2. Prints were made on Azo paper, glossy, white, smooth, grades 0-5 inclusive.

3. Processing was carried out as outlined.

4. The pressure was calculated as follows: weights were supported on one end of one pressure strap until it just started to pull away from the circular disk holding it down. These weights were then weighed and the value multiplied by two, since each strap acted on two sides of each half of the printing frame. This value was taken as the total pressure because the negative was mounted in only one-half of the printing frame.

Total value of weights = 17½ lbs.

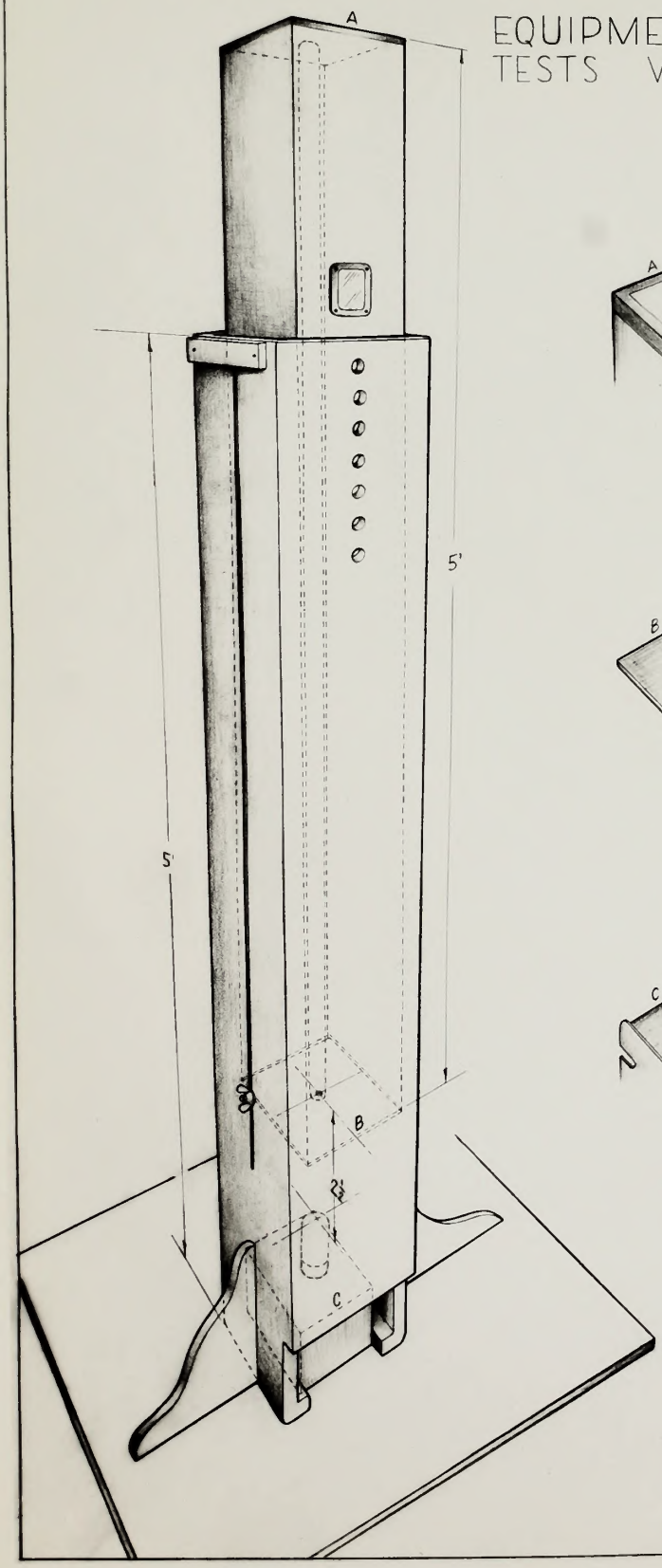
Total pressure on ½ of
frame = 35 lbs.

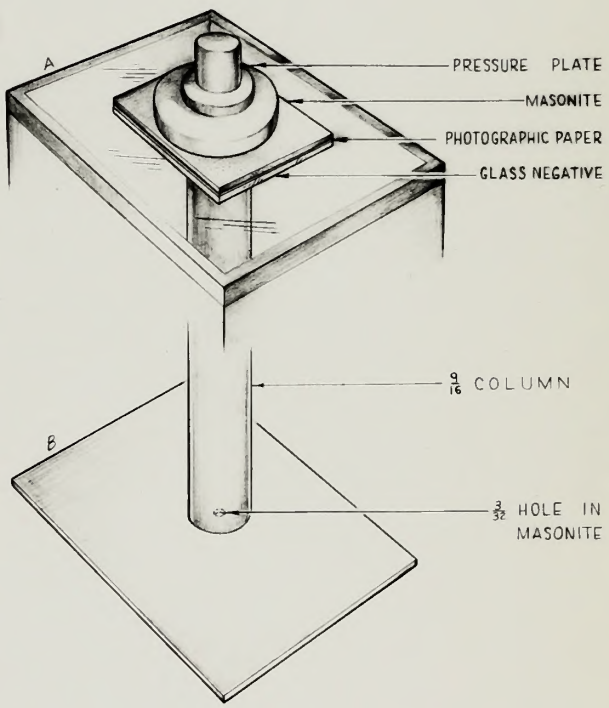
Total area of test object =(3x4) 12 sq. in.

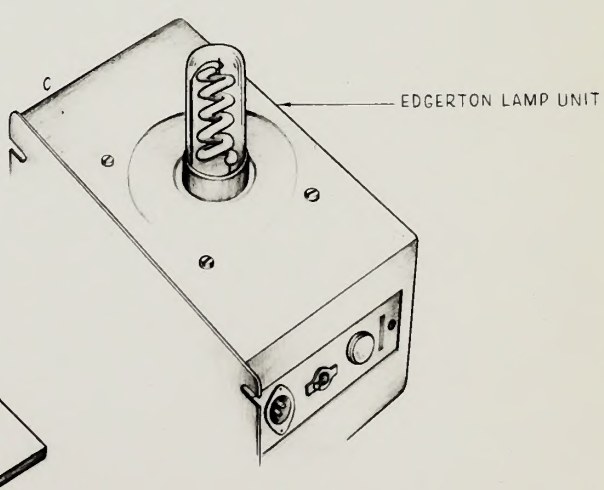
Calculated pressure per
sq. inch = 35\12 =2.917 P.S.I.

POINT SOURCE PRINTER

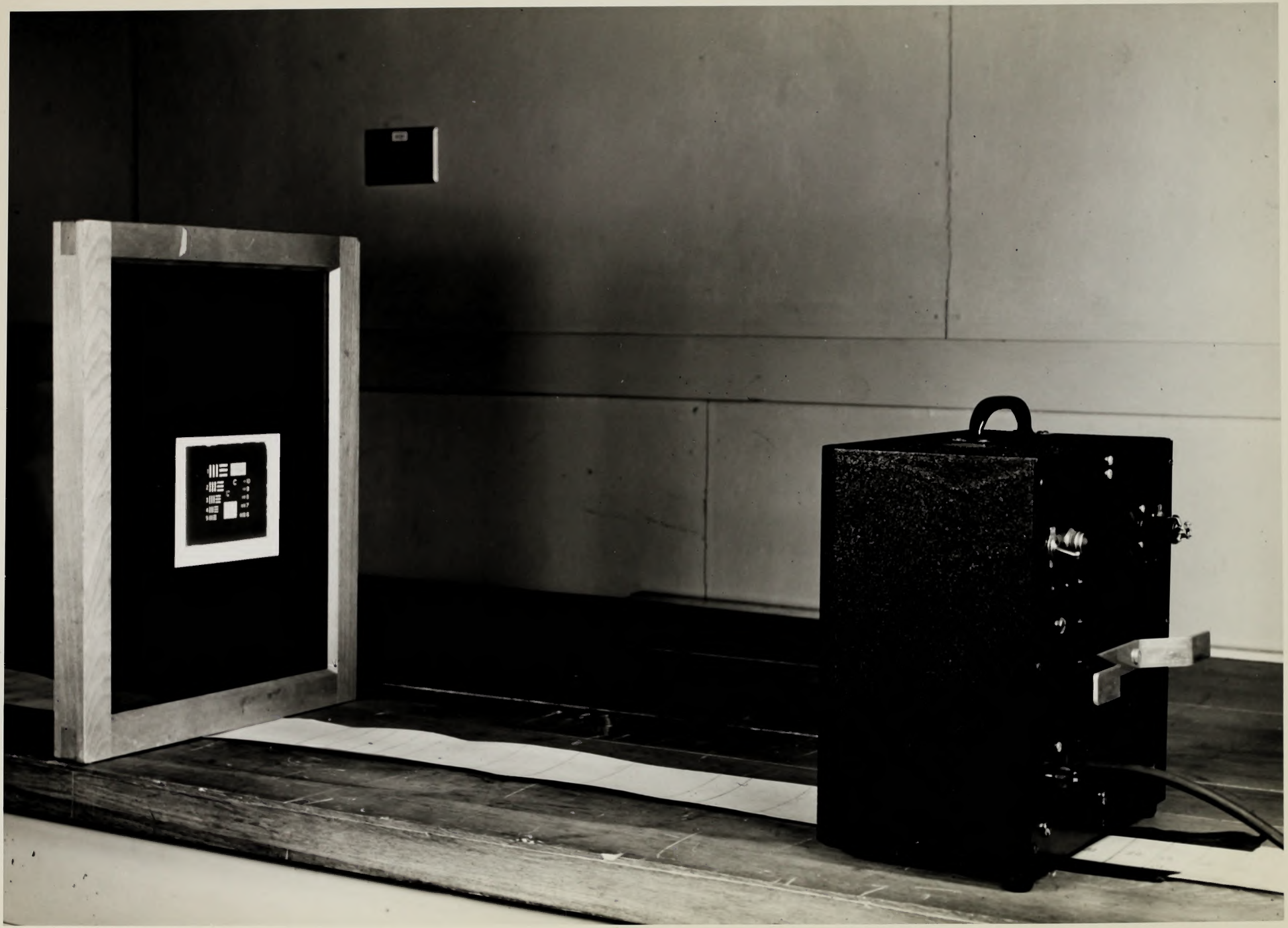
EQUIPMENT USED IN POINT SOURCE TESTS WITH EDGERTON LAMP.

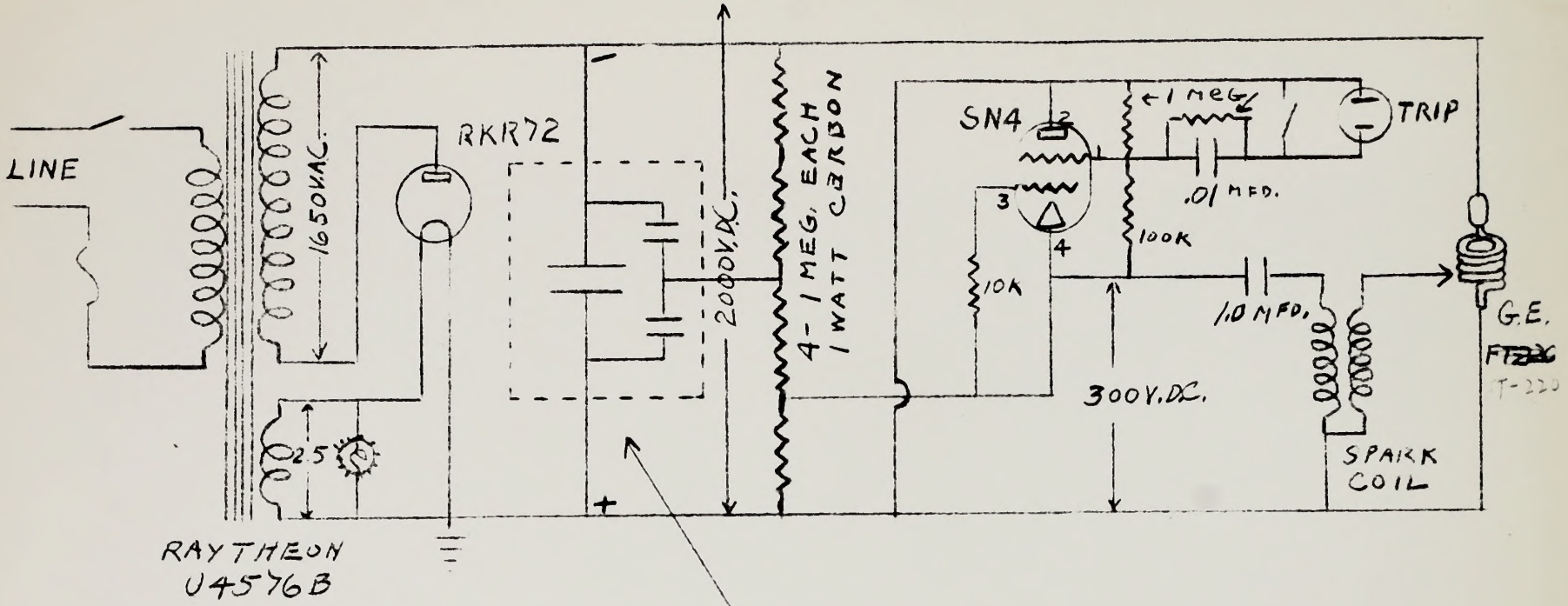






BOSTON UNIVERSITY
OPTICAL RESEARCH LABORATORY
JANUARY, NINETEEN FORTY SEVEN
SYLVIA MAYER




LINE
1650VAC.
RKR72
2000V.DC.
4-1 MEG. EACH 1 WATT CARBON
SN4
1 MEG
TRIP
.01 MFD.
100K
10K
1.0 MFD.
300V.DC.
G.E.
FT-220
SPARK COIL
25
RAYTHEON
U4576B
G.E. 25F800-G2
10 MFD. 660 A.C. 60 CY.
0.5 MFD. SPLITTERS BUILT IN
SUBSTITUTE ANY
SUITABLE CAPACITOR

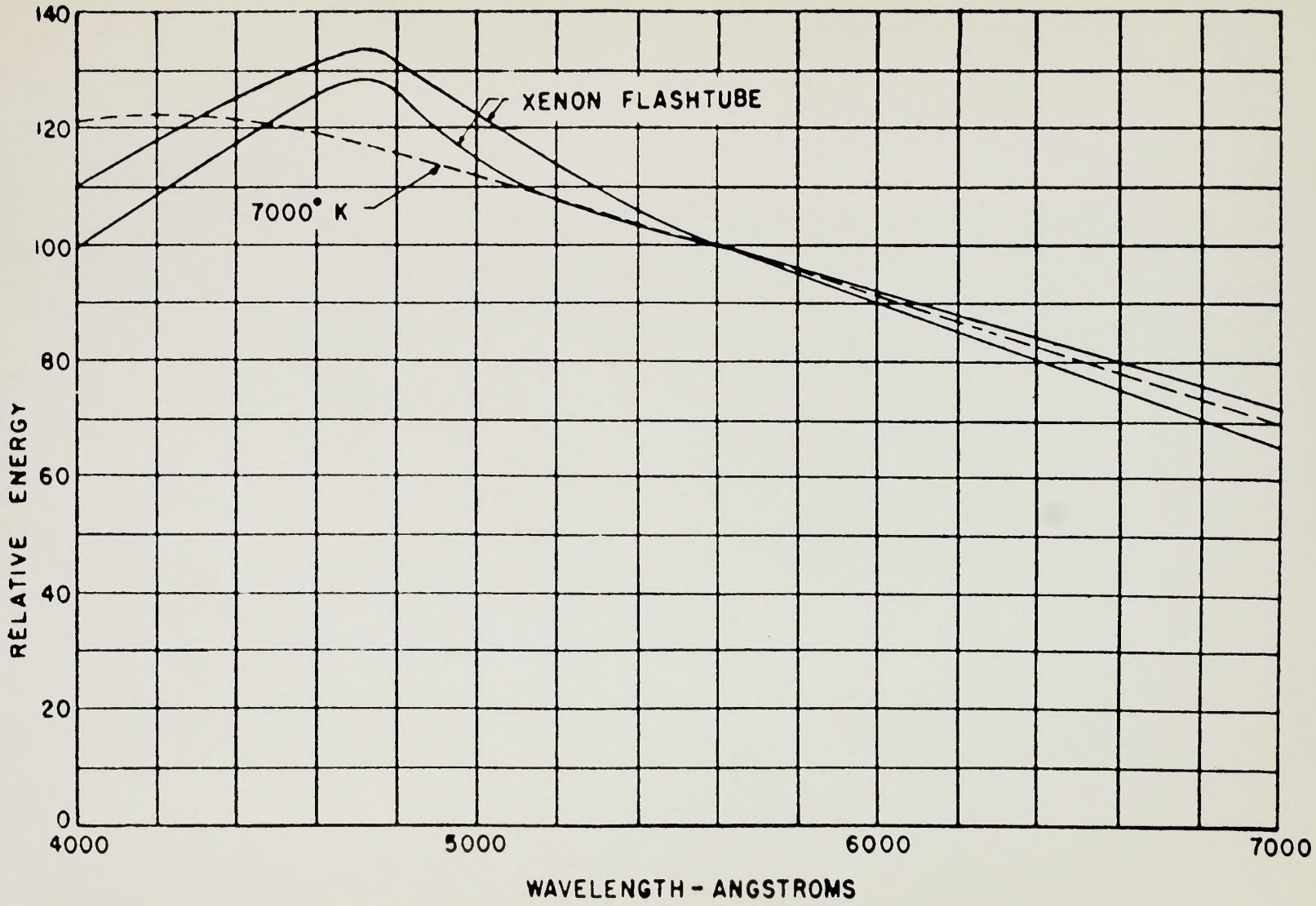


FIG. 10. The variations in relative output of helical xenon-filled flashtubes operating over a range of 60 to 480 watt-seconds at 2000 volts are included between the two solid curves.

C. TABLE OF RESULTS

(2) A-11 Printer - (Average of 5 observers)

Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) 1/mm.
0	1	22.60
	2	25.20
	4	25.20
	5	25.20
	6	31.75
	7	40.00
	8	31.75
	9	31.75
	10	29.57
	12	18.97
1	.2	25.20
	½	31.75
	1	25.20
	2	23.90
	4	20.00
	8	15.87
	12	13.42
2	.2	25.20
	½	33.85
	1	25.20
	2	25.20
	4	23.90
	8	7.94
	12	7.53
3	.2	30.11
	½	31.75
	1	25.20
	2	23.90
	4	12.77
	8	10.00
	12	7.53
4	.2	12.60
	½	31.75
	2	25.20
	3	25.20
	4	25.20
	8	19.24
	12	7.53
5	½	14.24
	1	15.87
	2	20.00

(2) A-II Printer - (Average of 5 observers)

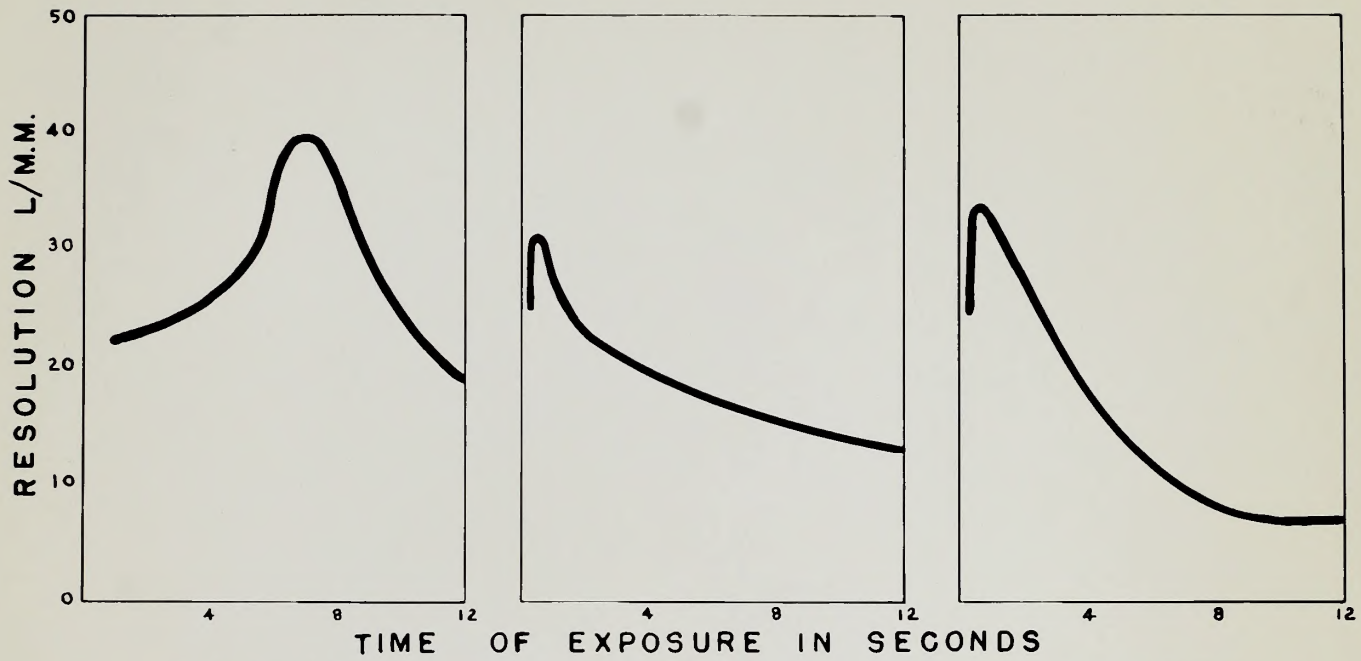
Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) l/mm.
0	1	22.60
	2	25.20
	4	25.20
	5	25.20
	6	31.75
	7	40.00
	8	31.75
	9	31.75
	10	29.57
	12	18.97
1	.2	25.20
	¼	31.75
	1	25.20
	2	23.90
	4	20.00
	8	15.87
	12	13.42
2	.2	25.20
	¼	33.85
	1	25.20
	2	25.20
	4	23.90
	8	7.94
	12	7.53
3	.2	30.11
	¼	31.75
	1	25.20
	2	23.90
	4	12.77
	8	10.00
	12	7.53
4	.2	12.60
	¼	31.75
	½	25.20
	1	25.20
	4	25.20
	8	19.24
	12	7.53
5	¼	14.24
	1	15.87
	2	20.00

A-11 Printer - (Continued)

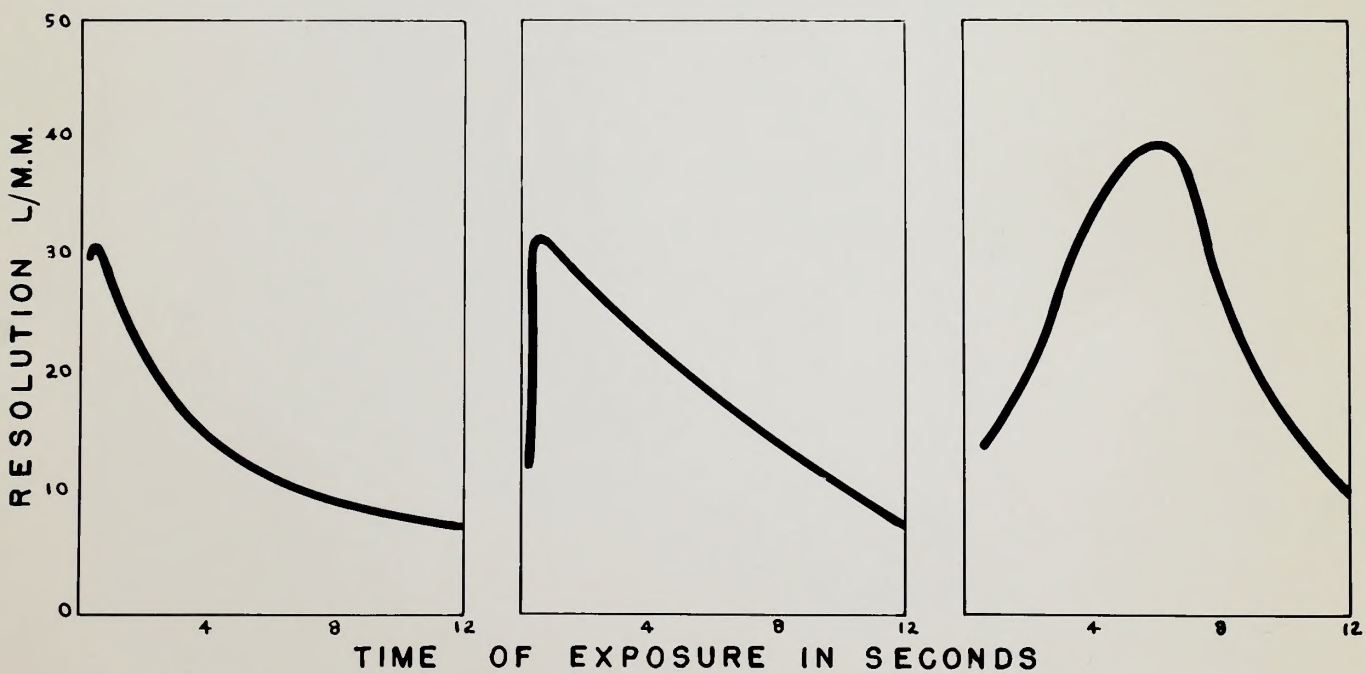
Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) 1/mm.
5	3	33.81
	5	33.81
	6	40.00
	8	26.84
	12	11.44

RESOLUTION-TIME CHARTS

CURVES OF TESTS ON AZO PAPER, GRADES 0-5, WITH ARMY A-11 PRINTER.



GRADE 0 GRADE 1 GRADE 2



GRADE 3 GRADE 4 GRADE 5

(1) A-14 Printer - (Average of 5 observers)

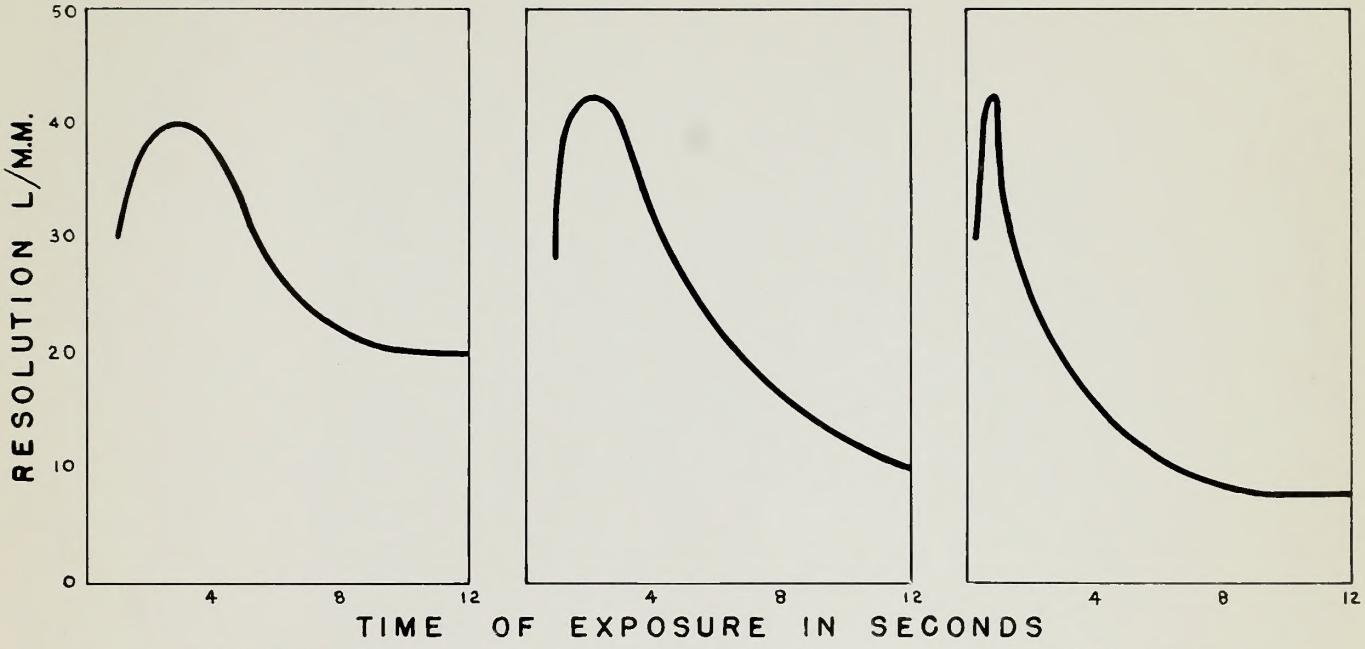
Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) 1/mm.
0	1	30.11
	2	40.00
	4	40.00
	5	31.75
	6	27.38
	7	21.73
	12	20.00
1	1	28.48
	2	42.60
	4	31.75
	8	15.87
	12	10.00
2	.2	30.11
	½	42.60
	1	33.81
	2	30.11
	4	15.05
	8	7.94
	12	7.94
3	2	35.88
	1	40.00
	2	28.48
	4	10.65
	8	10.65
	12	7.12
4	.2	21.30
	½	25.20
	1	42.60
	2	47.79
	4	11.30
	8	6.30
	12	5.32
5	.2	7.12
	½	22.60
	1	31.75
	2	40.00
	4	45.20
	8	15.05
	12	10.00

(1) A-14 Printer - (Average of 5 observers)

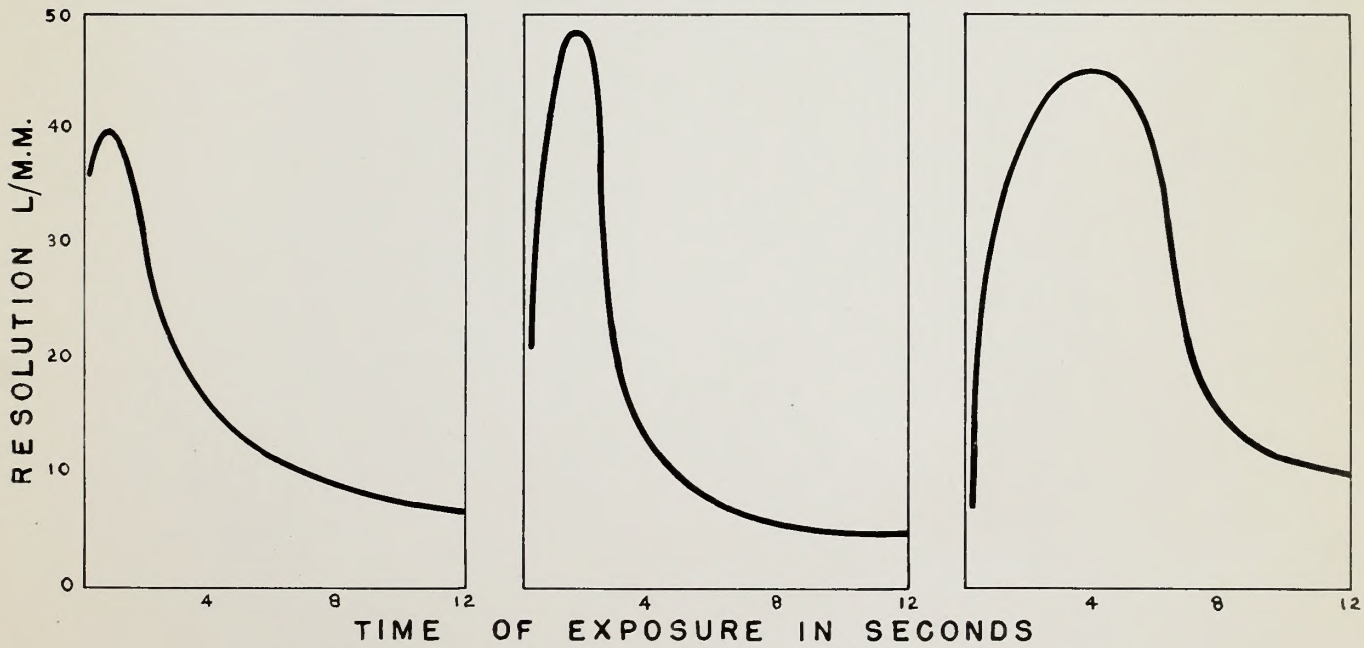
Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) l/mm.
0	1	30.11
	2	40.00
	4	40.00
	5	31.75
	6	27.38
	7	21.73
	12	20.00
1	1	28.48
	2	42.60
	4	31.75
	8	15.87
	12	10.00
2	.2	30.11
	1	42.60
	1	33.81
	2	30.11
	4	15.05
	8	7.94
	12	7.94
3	2	35.88
	1	40.00
	2	28.48
	4	10.65
	8	10.65
	12	7.12
4	.2	21.30
	1	25.20
	1	42.60
	2	47.79
	4	11.30
	8	6.30
	12	5.32
5	.2	7.12
	1	22.60
	1	31.75
	2	40.00
	4	45.20
	8	15.05
	12	10.00

RESOLUTION-TIME CHARTS

CURVES OF TESTS ON AZO PAPER, GRADES 0-5, WITH ARMY A-14 PRINTER.



GRADE 0 GRADE 1 GRADE 2



GRADE 3 GRADE 4 GRADE 5

(3) Kodak Printer - (Average of 5 observers)

Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) 1/mm.
0	1	40.00
	2	53.66
	4	60.22
	5	63.49
	6	63.49
	7	79.99
	8	56.94
	12	50.39
1	1	50.39
	2	56.94
	4	67.62
	5	79.99
	6	79.99
	7	79.99
	8	63.49
	12	42.60
2	1	40.00
	2	50.39
	4	63.49
	7	79.99
	8	71.74
	12	63.49
3	1	40.00
	2	50.39
	4	63.49
	5	79.99
	6	79.99
	7	79.99
	8	63.49
	12	23.90
4	1	26.84
	2	50.39
	4	53.66
	8	71.62
	10	79.99
	11	79.99
	12	79.99
	13	79.99
	14	79.99
	15	67.62
5	1	12.60
	2	25.20
	4	40.00
	8	50.39

(3) Kodak Printer - (Average of 5 observers)

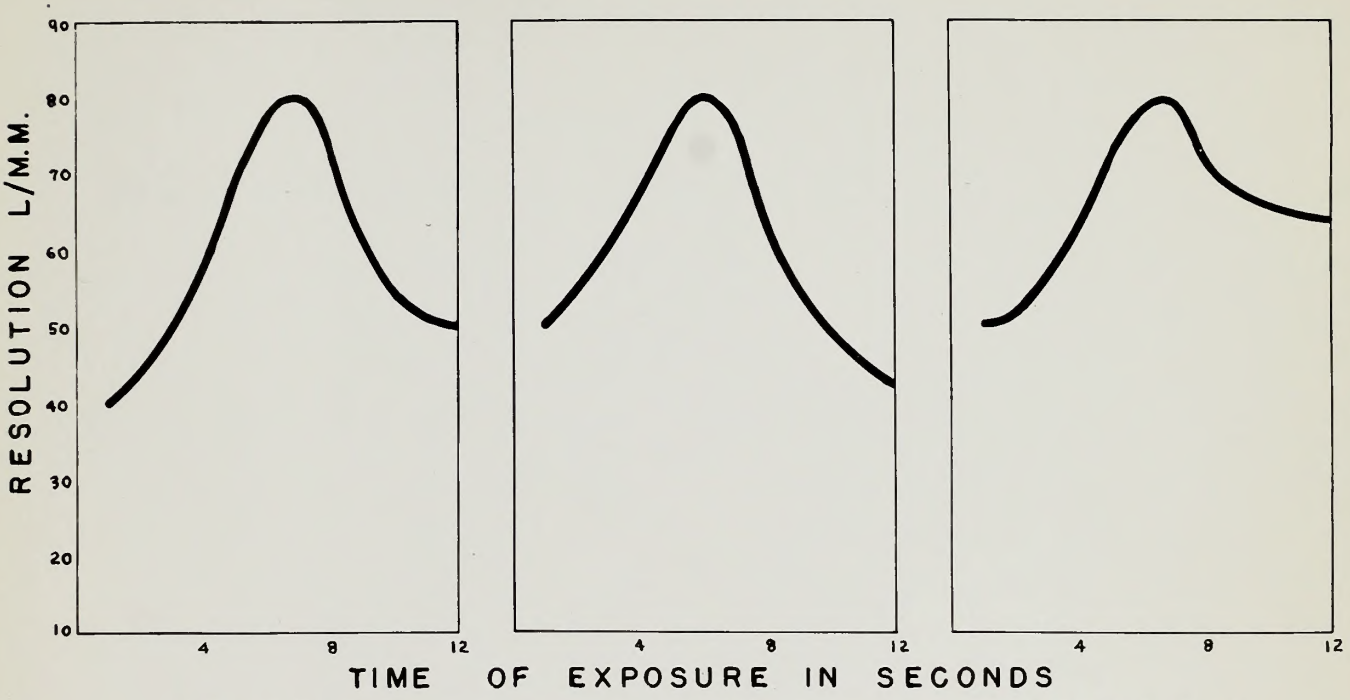
Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) l/mm.
0	1	40.00
	2	53.86
	4	60.22
	5	63.49
	6	63.49
	7	79.99
	8	56.94
	12	50.39
1	1	50.39
	2	56.94
	4	67.62
	5	79.99
	6	79.99
	7	79.99
	8	63.49
	12	42.60
2	1	40.00
	2	50.39
	4	63.49
	7	79.99
	8	71.74
	12	63.49
3	1	40.00
	2	50.39
	4	63.49
	5	79.99
	6	79.99
	7	79.99
	8	63.49
	12	23.90
4	1	26.84
	2	50.39
	4	53.86
	8	71.62
	10	79.99
	11	79.99
	12	79.99
	13	79.99
	14	79.99
	15	67.62
5	1	12.60
	2	25.20
	4	40.00
	8	50.39

(3) Kodak Printer - (Average of 5 observers) (Continued)

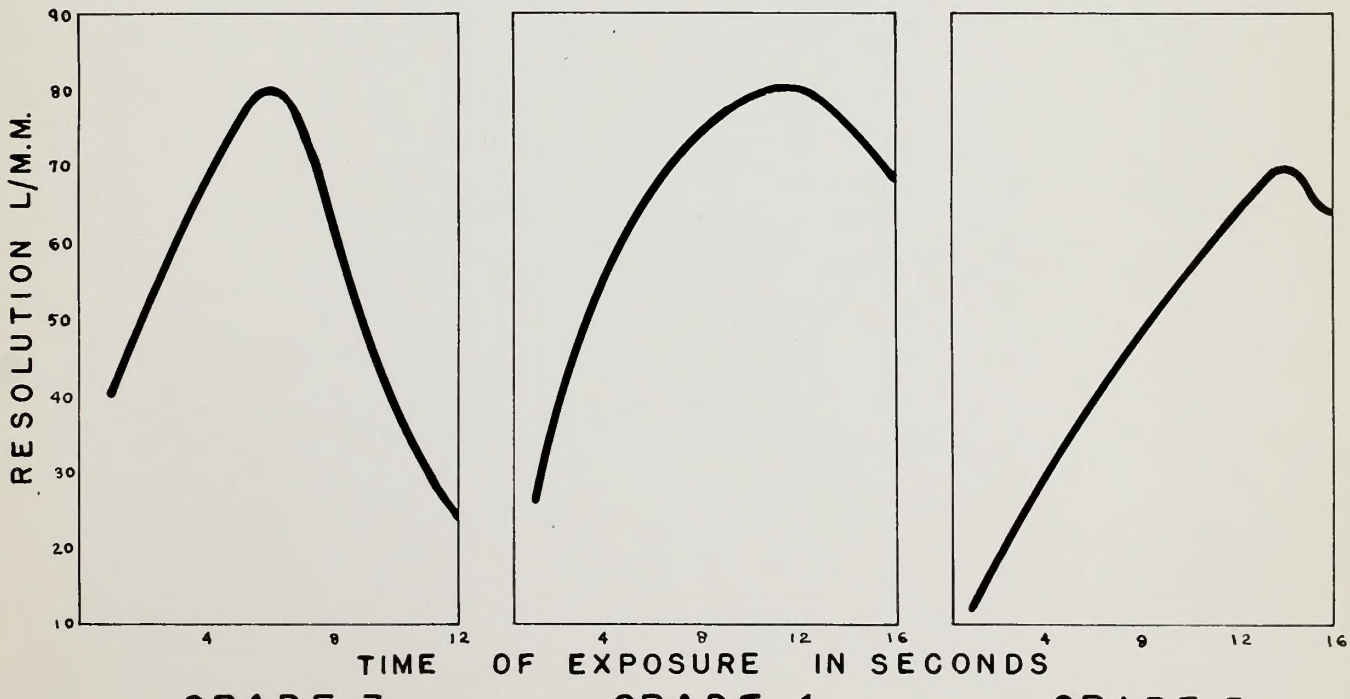
Paper Grade	Exposure Time (Seconds)	Resolution (Reflection) 1/mm.
5	11	63.49
	12	63.49
	13	63.49
	14	68.99
	15	63.49
	16	63.49

RESOLUTION-TIME CHARTS

CURVES OF TESTS ON AZO PAPER, GRADES 0-5, WITH KODAK PRINTER.



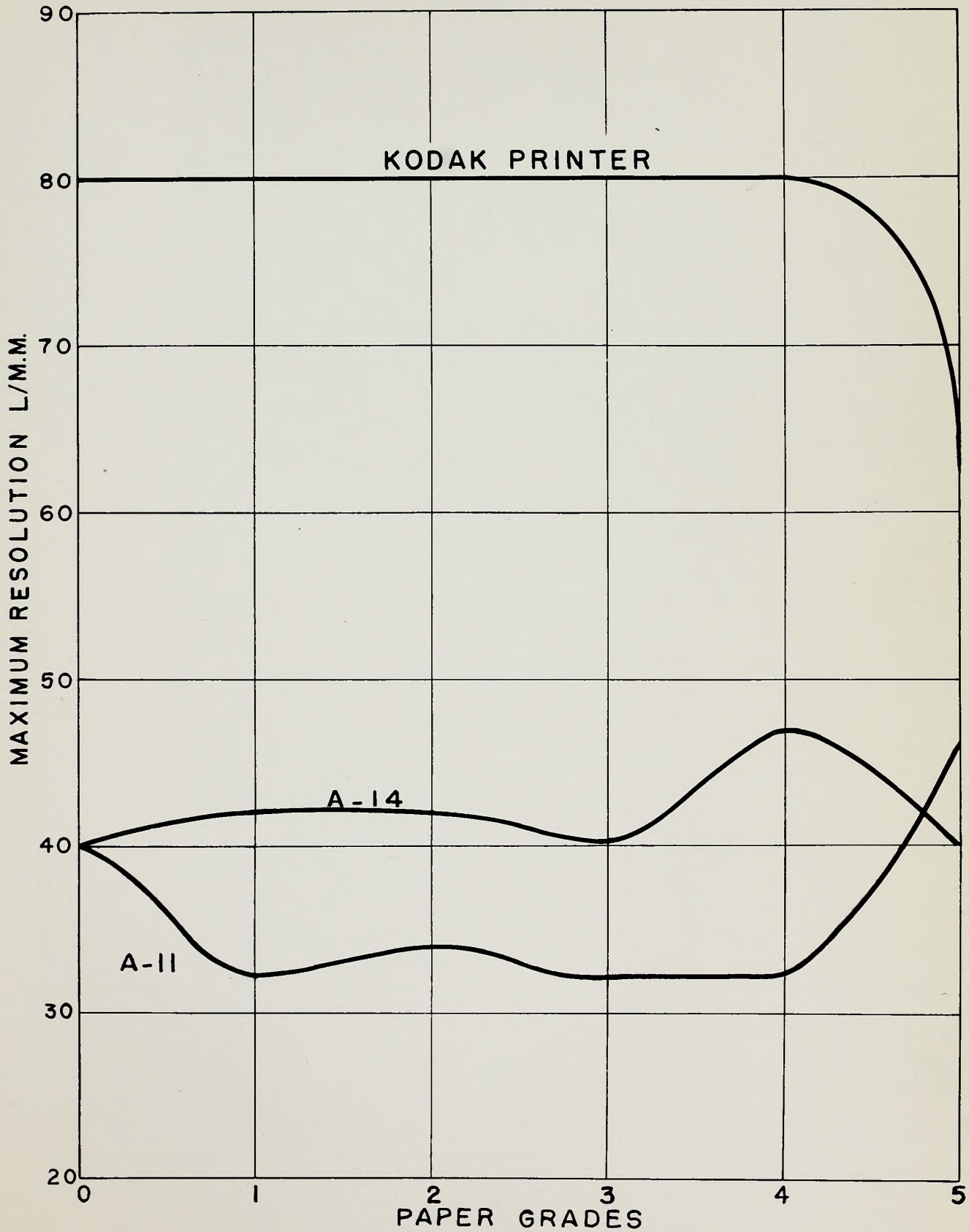
GRADE 0 GRADE 1 GRADE 2



GRADE 3 GRADE 4 GRADE 5

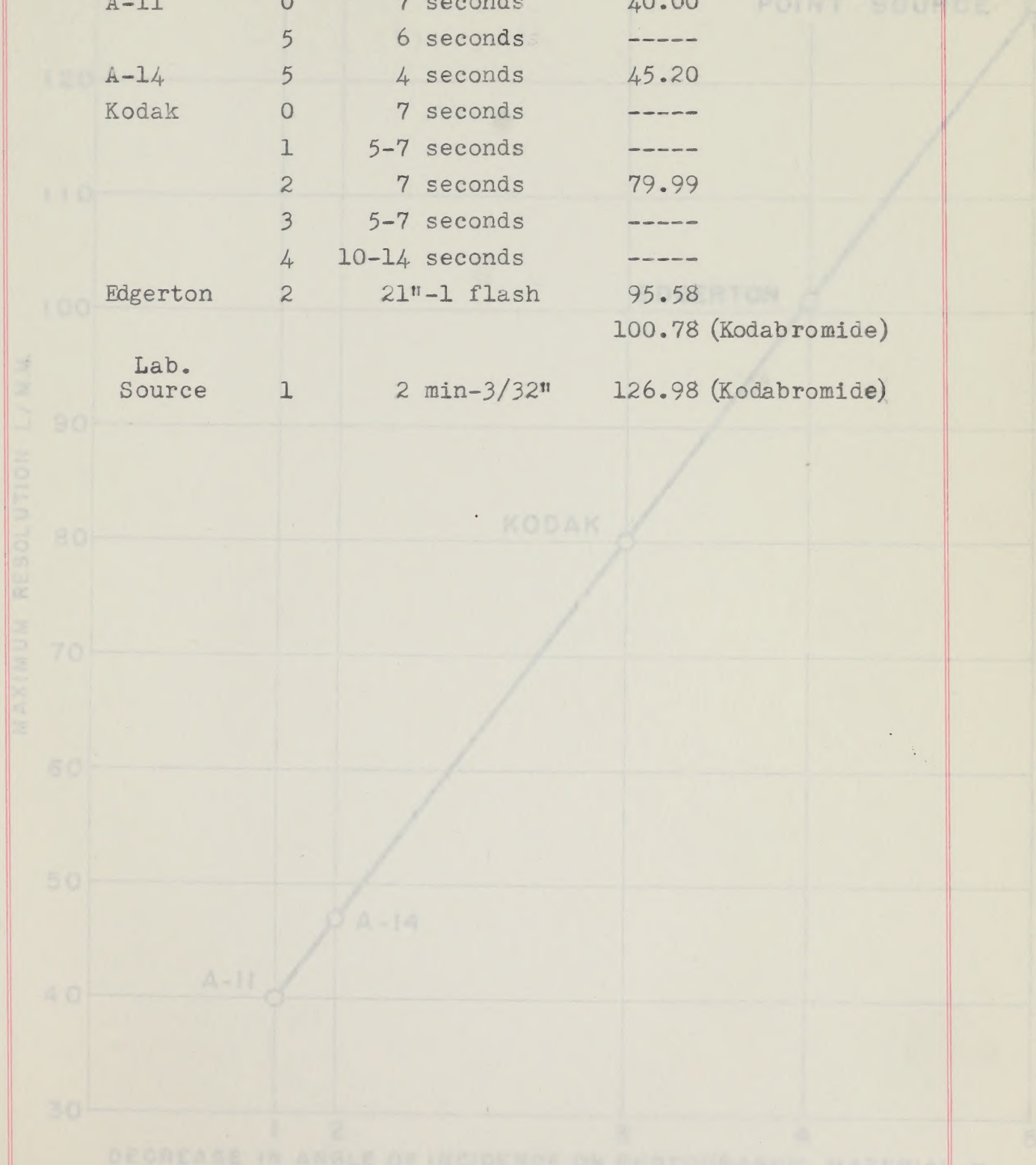
MAXIMUM RESOLUTION – GRADE CHART

CURVES OF TESTS ON AZO PAPER WITH A-11, A-14 AND KODAK PRINTER.



(4)

Source	Grade	Exposure	Resolution l/mm.
A-11	0	7 seconds	40.00
	5	6 seconds	-----
A-14	5	4 seconds	45.20
Kodak	0	7 seconds	-----
	1	5-7 seconds	-----
	2	7 seconds	79.99
	3	5-7 seconds	-----
	4	10-14 seconds	-----
Edgerton	2	21"-1 flash	95.58
			100.78 (Kodabromide)
Lab. Source	1	2 min-3/32"	126.98 (Kodabromide)

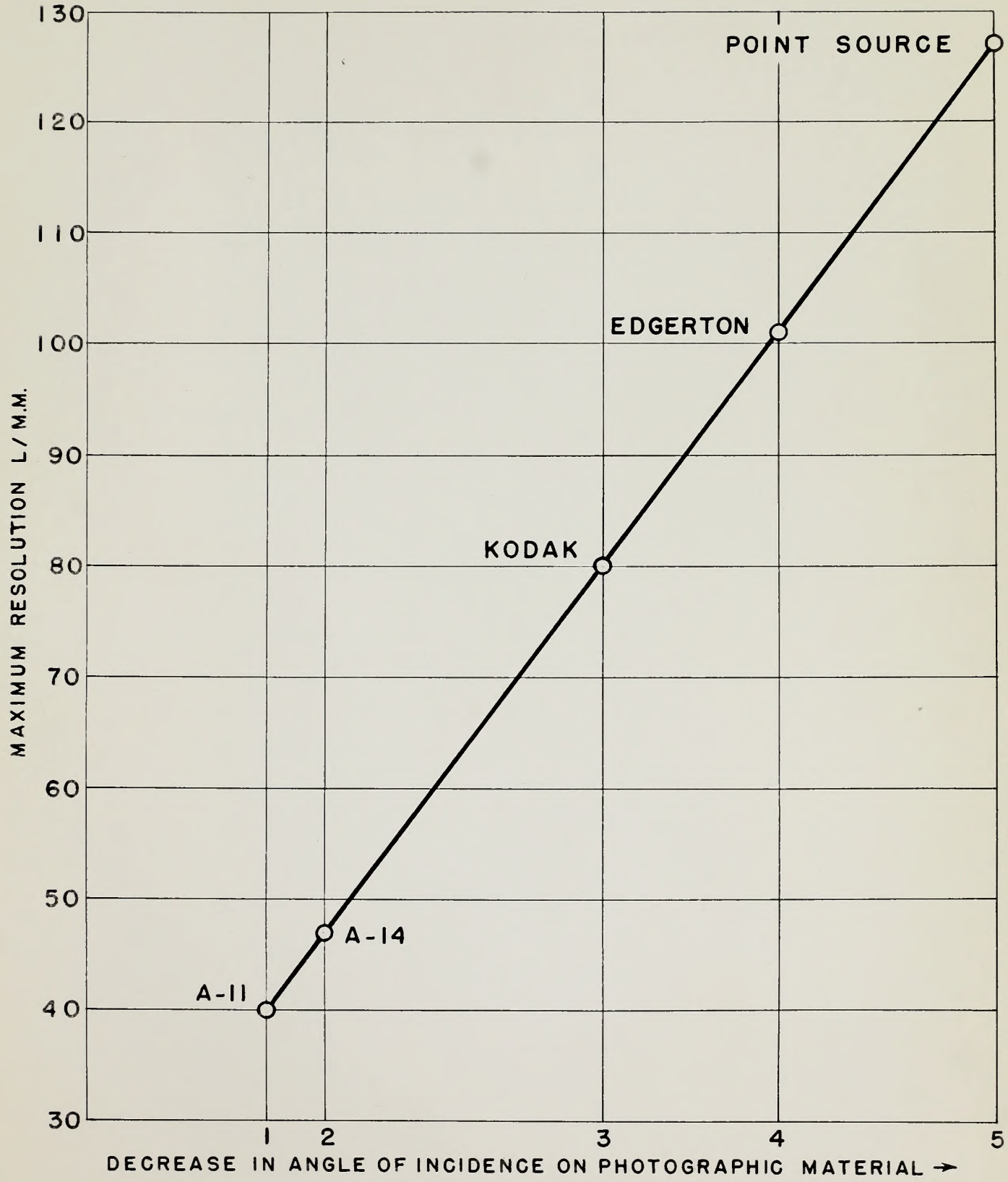


(4)

Source	Grade	Exposure	Resolution l/mm.
A-11	0	7 seconds	40.00
	5	6 seconds	-----
A-14	5	4 seconds	45.20
Kodak	0	7 seconds	-----
	1	5-7 seconds	-----
	2	7 seconds	79.99
	3	5-7 seconds	-----
	4	10-14 seconds	-----
Edgerton	2	21"-1 flash	95.58
			100.78 (Kodabromide)
Lab. Source	1	2 min-3/32"	126.98 (Kodabromide)

MAXIMUM RESOLUTION–ANGLE OF INCIDENCE

PLOT OF TESTS ON VARIOUS PRINTERS



(5) Laboratory Point Source Printer

Paper	Grade	Source	Description	Resolution (Reflection) 1/mm
Azo	F-1	Edgerton	¼" Aperture with ground glass	
			(1) 2 flashes	23.90
			(2) 5 flashes	40.00
			(3) 8 flashes	50.39
Azo	F-1	Edgerton	1" Aperture No Glass	
			(1) 20 flashes	50.39
			(2) 30 flashes	63.49
	F-5		(1) 20 flashes	5.65
			(2) 30 flashes	8.97
	F-1	100W	(1) 15 seconds	31.75
			(2) 30 seconds	50.39
	F-5		(1) 45 seconds	63.49
			(2) 60 seconds.	63.49
	F-1	300W	(1) 5 seconds	40.00
			(2) 15 seconds	63.49
			(3) 25 seconds	67.62
			(4) 35 seconds	79.99
Kodabromide	F-1	300W	3/32" Aper. 5' Column	
			(1) 15 seconds	50.39
			(2) 30 seconds	63.49
			(3) 60 seconds	79.99
			(4) 120 seconds	126.98
			(5) 180 seconds	95.58
Kodabromide	F-1	300W	.0135" Aperture Column	
			(1) 90 minutes	25.54 (7)
			(2) 125 minutes	31.75 (7)
			(3) 3½ hours	28.48 (9)
			3/32" Aperture Column	
			(1) 15 minutes - no image formation	
			(2) 25 minutes - slight image formation	

(5) Laboratory Point Source Printer

Paper	Grade	Source	Description	Resolution (Reflection) l/mm
Azo	F-1	Edgerton	¼" Aperture With ground glass	
			(1) 2 flashes	23.90
			(2) 5 flashes	40.00
			(3) 8 flashes	50.39
Azo	F-1	Edgerton	1" Aperture No Glass	
			(1)20 flashes	50.39
			(2)30 flashes	63.49
	F-5		(1)20 flashes	5.65
			(2)30 flashes	8.97
	F-1	100W	(1)15 seconds	31.75
			(2)30 seconds	50.39
	F-5		(1)45 seconds	63.49
			(2)60 seconds.	63.49
	F-1	300W	(1) 5 seconds	40.00
			(2)15 seconds	63.49
			(3)25 seconds	67.62
			(4)35 seconds	79.99
Kodabromide	F-1	300W	3/32" Aper. 5' Column	
			(1)15 seconds	50.39
			(2)20 seconds	63.49
			(3)60 seconds	79.99
			(4)120 seconds	126.98
			(5)180 seconds	95.38
Kodabromide	F-1	300W	.0135" Aperture Column	
			(1) 90 minutes	25.54 (7)
			(2)125 minutes	31.75 (7)
			(3) 3½ hours	28.48 (9)
			3/32" Aperture Column	
			(1) 15 minutes - no image formation	
			(2) 25 minutes - slight image formation	

D. CONCLUSIONS

1. It has been shown that the Army A-14 Printer gives higher resolution than the Army A-11 Printer under identical conditions. The Army A-11 Printer, however, reached maximum value on Grades 1-4 faster than the A-14.

The following chart gives a complete comparison of the two printers:

Grade		Max. Value Time in Sec.		Average over Range 1/mm		Maximum Resolution Value 1/mm	
A-14	A-11	A-14	A-11	A-14	A-11	A-14	A-11
0	0	2-4	7	30.14	28.20	40.00	40.00
1	1	2	½	25.74	22.19	42.60	31.75
2	2	½	½	23.94	21.26	42.60	33.85
3	3	1	½	22.13	20.18	40.00	31.75
4	4	2	½	22.83	20.96	47.79	31.75
5	5	4	6	24.53	24.50	45.20	40.00
			AVE:	24.89	22.88	43.03	34.83

2. The source used in printing has a very great effect on print resolution. The closer we approach either parallel or point source light the higher will be the value of resolution. This is shown very well in the graph following page 11 which is a plot of maximum resolution with each source. As we go from a highly diffuse source at the lower end to a very small divergent source we increase the resolution about 300%.

CHAPTER II

A. Statement of the Problem:

1. Comparison of print resolution of contact and enlarging papers on glossy and semi-matte surfaces.

B. Experimental Procedure:

1. Materials

a) Test Object:

The negative used in this work was a U.S. Army test object of infinite contrast and maximum resolution of 200 l/mm. (See Frontispiece)

b) Positive Material:

1. Azo Paper
   (a) Grades 0-5, glossy, white, smooth
   (b) Grades 1-5, semi-matte, white, smooth
2. Velox Paper
   (a) Grades 0-5, glossy, white, smooth
3. Kodabromide Paper
   (a) Grades 1-5, glossy, white, smooth
   (b) Grades 1-4, semi-matte, white, smooth

2. Processing Conditions:

(See Chapter I under "Processing Procedures for Entire Research")

3. Discussion of Experiments

a) Edgerton Flash Unit:

1. Description. (See Chapter I (e))
2. Prints were made on:
   (a) Azo Paper, glossy, white, smooth
   (b) Azo Paper, semi-matte, white, smooth
   (c) Velox Paper, glossy, white, smooth
   (d) Kodabromide Paper, glossy, white, smooth
   (e) Kodabromide Paper, semi-matte, white, and smooth.

3. Processing was carried out as outlined.
4. Pressure was equal to 2.917 lbs./sq. in.

3. Processing was carried out as outlined.
4. Pressure was equal to 2.917 lbs./sq. in.

C. Table of Results

C. Table of Results

Velox (Glossy) (Reflection)

(Average of 4 observers)

Resolution in l/mm

F-0	F-1	F-2
3" - 24.43	3" - 6.96	3" - 10.00
5" - 36.00	5" - 8.76	6" - 15.22
7" - 36.70	7" - 10.00	7" - 28.09
8" - 50.93	8" - 10.52	8" - 33.40
9" - 58.25	9" - 11.56	9" - 40.00
10" - 63.49	10" - 13.39	10" - 42.08
11" - 66.79	11" - 14.70	11" - 44.70
12" - 66.79	12" - 17.08	12" - 44.70
13" - 70.09	13" - 25.70	15" - 50.39
14" - 76.69	14" - 29.13	18" - 53.67
15" - 79.99	15" - 30.54	21" - 53.67
16" - 67.62	18" - 37.94	24" - 71.74
18" - 63.49	22" - 45.20	25" - 79.99
	24" - 53.66	26" - 79.99
	26" - 61.06	27" - 79.99
	27" - 79.99	28" - 79.99
	28" - 79.99	29" - 86.92
	29" - 83.45	30" - 79.99
	30" - 86.92	
	31" - 79.99	

F-3	F-4	F-5
3" - 21.57	1" - 50.39	3" - 8.52
4" - 70.09	2" - 60.22	5" - 10.52
5" - 70.09	3" - 73.39	7" - 12.08
6" - 76.69	4" - 63.49	8" - 16.57
7" - 63.49	5" - 63.49	9" - 79.99
8" - 63.49	7" - 60.87	10" - 85.19
9" - 63.49	9" - 50.39	11" - 84.15
10" - 63.49	11" - 46.23	13" - 76.69
12" - 60.87	13" - 40.00	14" - 75.87
15" - 50.39	15" - 37.94	15" - 75.87
18" - 50.39	18" - 31.75	18" - 67.62

*Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure

Velox (Glossy) (Reflection)

(Average of 4 observers)

Resolution in l/mm

F-0	F-1	F-2
3" - 24.43	3" - 6.96	3" - 10.00
5" - 36.00	5" - 8.76	6" - 15.12
7" - 36.70	7" - 10.00	7" - 28.09
8" - 50.23	8" - 10.32	8" - 33.40
9" - 58.25	9" - 11.56	9" - 40.00
10" - 63.49	10" - 13.39	10" - 45.08
11" - 66.79	11" - 14.70	11" - 44.70
12" - 66.79	12" - 17.08	12" - 44.70
13" - 70.09	13" - 25.70	13" - 50.39
14" - 76.69	14" - 29.13	14" - 53.67
15" - 79.99	15" - 30.54	21" - 53.67
16" - 67.62	16" - 37.34	24" - 71.74
16" - 63.49	22" - 45.20	25" - 79.99
	24" - 53.86	26" - 79.99
	26" - 61.06	27" - 79.99
	27" - 79.99	28" - 79.99
	28" - 79.99	29" - 86.92
	29" - 83.45	30" - 79.99
	30" - 86.92	
	31" - 79.99	

F-3	F-4	F-5
3" - 21.57	1" - 50.39	3" - 5.32
4" - 70.09	2" - 80.32	5" - 10.32
5" - 73.09	3" - 63.34	7" - 14.06
6" - 76.69	4" - 62.43	8" - 16.37
7" - 63.49	5" - 63.49	9" - 17.92
8" - 63.49	7" - 60.67	10" - 83.79
9" - 63.49	9" - 50.39	11" - 84.15
10" - 63.49	12" - 46.23	13" - 76.69
12" - 60.67	13" - 40.00	14" - 75.87
15" - 50.39	15" - 37.74	15" - 75.87
16" - 50.39	16" - 31.75	16" - 67.62

Note: The distances referred to above are the distance from the Edgerton Unit to the printing frame during the exposure

Velox (Glossy) (Transmission)

(Average of 4 observers)

Resolution in 1/mm

F-0	F-1	F-2
3" - 42.08	3" - 13.25	3" - 25.20
5" - 48.31	5" - 16.70	6" - 32.09
7" - 48.31	7" - 22.56	7" - 38.35
8" - 49.35	8" - 26.51	8" - 40.00
9" - 50.39	9" - 28.09	9" - 40.00
10" - 51.70	10" - 31.75	10" - 40.00
11" - 53.01	11" - 33.40	11" - 41.04
12" - 55.63	12" - 35.05	12" - 42.08
13" - 56.94	13" - 38.35	15" - 43.12
14" - 58.25	14" - 40.00	18" - 44.16
16" - 63.49	15" - 40.43	20" - 45.20
18" - 58.25	18" - 42.08	24" - 60.22
	22" - 47.79	25" - 63.49
	24" - 50.39	26" - 63.49
	26" - 60.22	27" - 63.49
	27" - 63.49	28" - 79.99
	28" - 68.99	29" - 66.24
	29" - 71.74	
	30" - 79.99	
	31" - 68.99	

F-3	F-4	F-5
3" - 48.31	1" - 45.20	3" - 12.08
4" - 63.49	2" - 53.66	5" - 19.39
5" - 63.49	3" - 63.49	7" - 38.35
6" - 62.18	5" - 60.87	9" - 70.09
7" - 60.87	7" - 50.39	10" - 75.86
8" - 53.01	9" - 46.23	11" - 70.09
9" - 50.39	11" - 40.00	12" - 67.62
10" - 49.35	13" - 30.44	13" - 63.49
12" - 46.23	15" - 25.20	14" - 63.49
15" - 40.00	18" - 20.00	15" - 63.49
18" - 36.70		18" - 60.87

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Velox (Glossy) (Translation)

(Average of 4 observers)

Resolution in l/mm

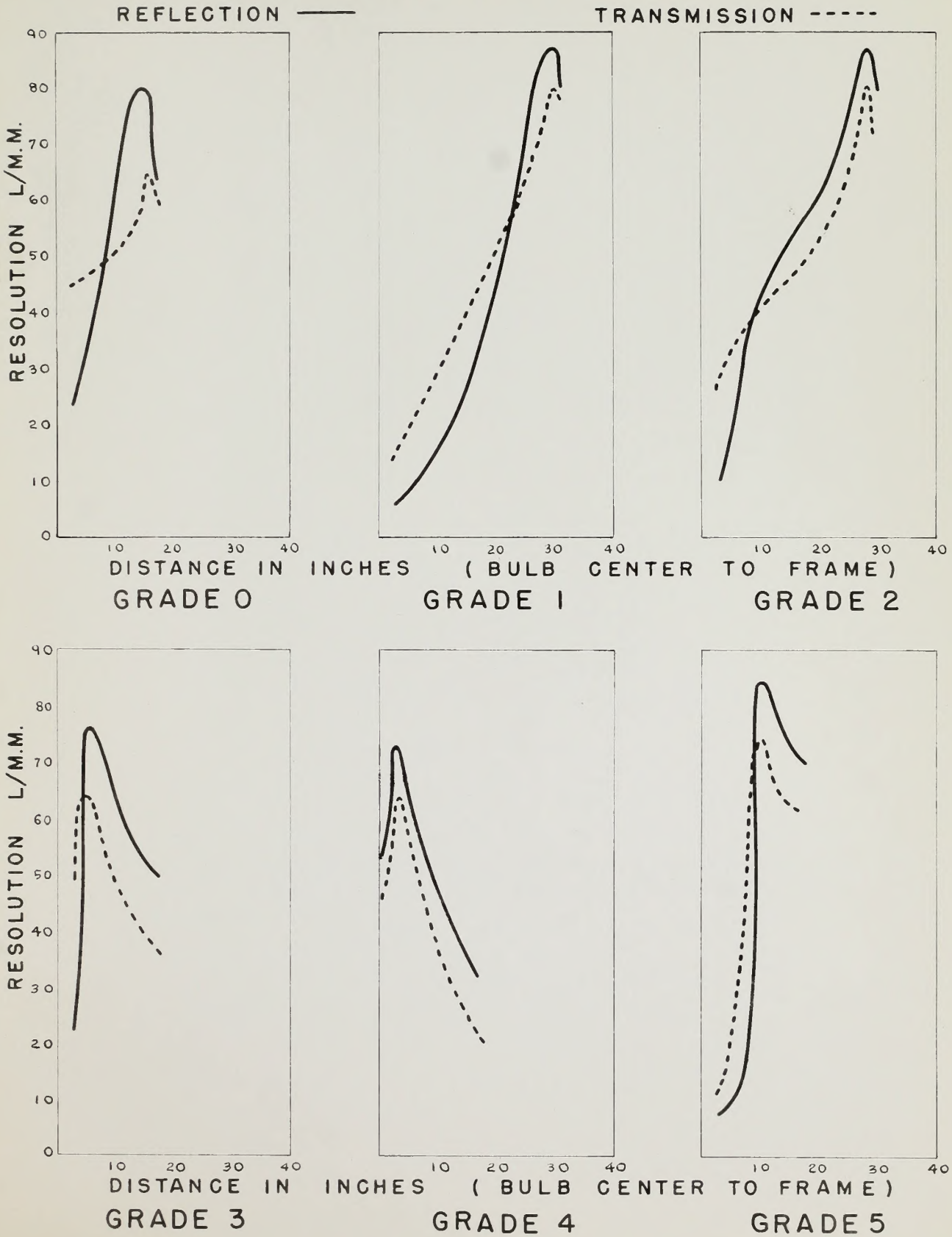
F-0	F-1	F-2
3" - 42.08	3" - 13.25	3" - 25.20
5" - 48.31	5" - 16.70	6" - 32.09
7" - 48.31	7" - 22.56	7" - 38.35
8" - 49.39	8" - 26.51	8" - 40.00
9" - 50.39	9" - 26.09	9" - 40.00
10" - 51.70	10" - 31.75	10" - 40.00
11" - 53.01	11" - 33.40	11" - 41.04
12" - 55.63	12" - 35.05	12" - 42.08
13" - 56.94	13" - 36.35	13" - 43.12
14" - 56.25	14" - 40.00	14" - 44.16
16" - 63.49	15" - 40.43	20" - 45.20
18" - 36.25	16" - 42.08	24" - 60.32
	22" - 47.79	25" - 63.49
	24" - 50.39	26" - 63.49
	26" - 60.32	27" - 63.49
	27" - 63.49	28" - 79.99
	28" - 68.99	30" - 66.24
	29" - 71.74	
	30" - 73.99	
	31" - 68.99	

F-3	F-4	F-5
3" - 48.31	1" - 43.20	3" - 12.08
4" - 63.49	2" - 53.56	5" - 19.39
5" - 63.49	3" - 63.49	7" - 38.35
6" - 62.18	5" - 60.87	9" - 70.09
7" - 60.87	7" - 50.39	10" - 75.86
8" - 53.01	9" - 46.23	11" - 70.09
9" - 50.39	11" - 40.00	12" - 67.02
10" - 49.35	13" - 30.44	13" - 65.49
12" - 40.23	15" - 25.20	14" - 65.49
15" - 40.00	18" - 20.00	15" - 63.49
18" - 36.70		18" - 60.87

Note: The distances referred to above are the distances from the Eagerton Unit to the printing frame during the exposure.

RESOLUTION-DISTANCE CHARTS

CURVES OF TESTS ON VELOX GLOSSY PAPER, GRADES 0-5, WITH EDGERTON UNIT.



Kodabromide (Glossy) (Reflection)

(Average of 4 observers)

Resolution in l/mm

F-1

30" - 47.79
40" - 79.99
43" - 85.19
46" - 85.19
50" - 90.39
53" - 90.39
56" - 85.19
60" - 79.99
70" - 75.87
80" - 63.49

F-2

30" - 10.00
40" - 12.60
50" - 28.48
70" - 85.19
80" - 85.19
86" - 85.19
88" - 85.19
89" - 86.92
90" - 93.85
92" - 97.82
94" -100.78
96" - 79.99

F-3

30" - 7.12
40" - 8.97
50" - 18.97
60" - 79.99
65" - 85.19
70" - 95.58
75" - 85.19
80" - 79.99

F-4

30" - 7.94
40" - 21.04
50" - 79.99
55" - 79.99
60" - 91.46
65" - 79.99
70" - 79.99
80" - 79.99

F-5

25" - 79.99
30" - 85.19
33" - 85.19
36" - 85.19
40" - 95.58
50" - 79.99
60" - 63.49

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Kodabromide (Glossy) (Reflection)

(Average of 4 observers)

Resolution in l/mm

F-1	F-2	F-3
30" - 47.79	30" - 10.00	30" - 7.12
40" - 79.99	40" - 12.60	40" - 8.97
43" - 85.19	50" - 28.48	50" - 18.97
46" - 85.19	70" - 85.19	60" - 79.99
50" - 90.39	80" - 85.19	65" - 85.19
53" - 90.39	86" - 85.19	70" - 95.58
56" - 85.19	88" - 85.19	75" - 85.19
60" - 79.99	89" - 86.92	80" - 79.99
70" - 75.87	90" - 93.85	
80" - 63.49	92" - 97.82	
	94" -100.78	
	96" - 79.99	

F-4	F-5
30" - 7.94	25" - 79.99
40" - 21.04	30" - 85.19
50" - 79.99	33" - 85.19
55" - 79.99	36" - 85.19
60" - 91.46	40" - 95.58
65" - 79.99	50" - 79.99
70" - 79.99	60" - 63.49
80" - 79.99	

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Kodabromide (Glossy) (Transmission)

(Average of 4 observers)

Resolution in l/mm

F-1

30" - 48.31
40" - 50.39
43" - 67.62
46" - 67.62
50" - 73.39
53" - 79.99
56" - 67.62
60" - 63.49
70" - 60.22
80" - 50.39

F-2

30" - 17.52
40" - 25.20
50" - 40.43
70" - 65.98
80" - 65.98
86" - 71.74
88" - 73.80
89" - 77.24
90" - 79.99
92" - 66.24
94" - 63.49
96" - 63.49

F-3

30" - 14.56
40" - 15.87
50" - 40.00
60" - 63.49
65" - 71.74
70" - 75.87
75" - 75.87
80" - 67.62

F-4

30" - 18.20
40" - 45.20
50" - 63.49
55" - 68.46
60" - 63.49
65" - 63.49
70" - 63.49
80" - 63.49

F-5

25" - 72.59
30" - 72.59
33" - 75.86
36" - 71.74
40" - 71.74
50" - 71.74
60" - 50.39

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Kodabromide (Glossy) (Transmission)

(Average of 4 observers)

Resolution in l/mm

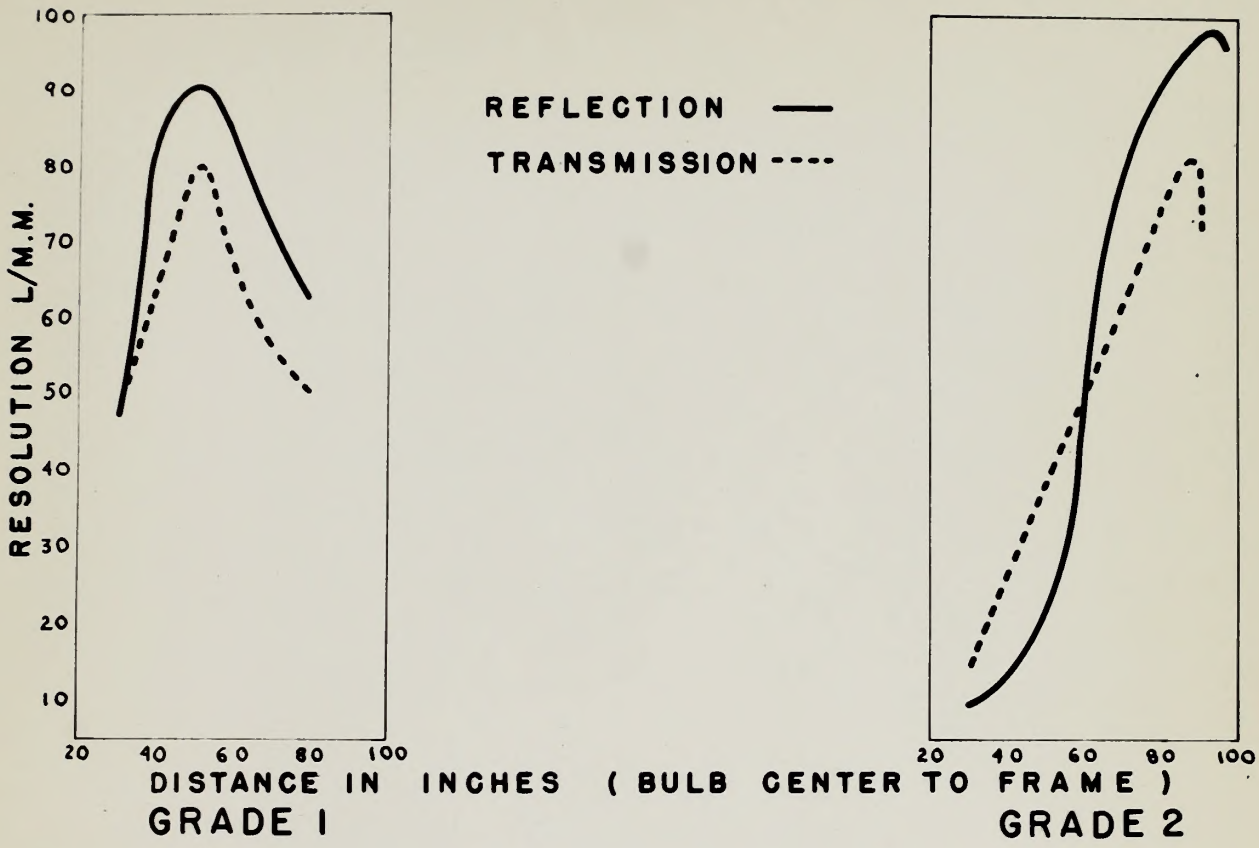
F-1	F-2	F-3
30" - 48.31	30" - 17.52	30" - 12.56
40" - 50.39	40" - 25.20	40" - 15.87
43" - 67.52	50" - 40.43	50" - 40.00
46" - 67.52	70" - 65.98	60" - 63.49
50" - 73.39	80" - 65.98	63" - 71.74
53" - 79.99	86" - 71.74	70" - 75.87
56" - 67.52	88" - 73.80	75" - 75.87
60" - 63.49	89" - 77.84	80" - 67.52
70" - 60.22	90" - 79.99	
80" - 50.39	92" - 66.24	
	94" - 63.49	
	96" - 63.49	

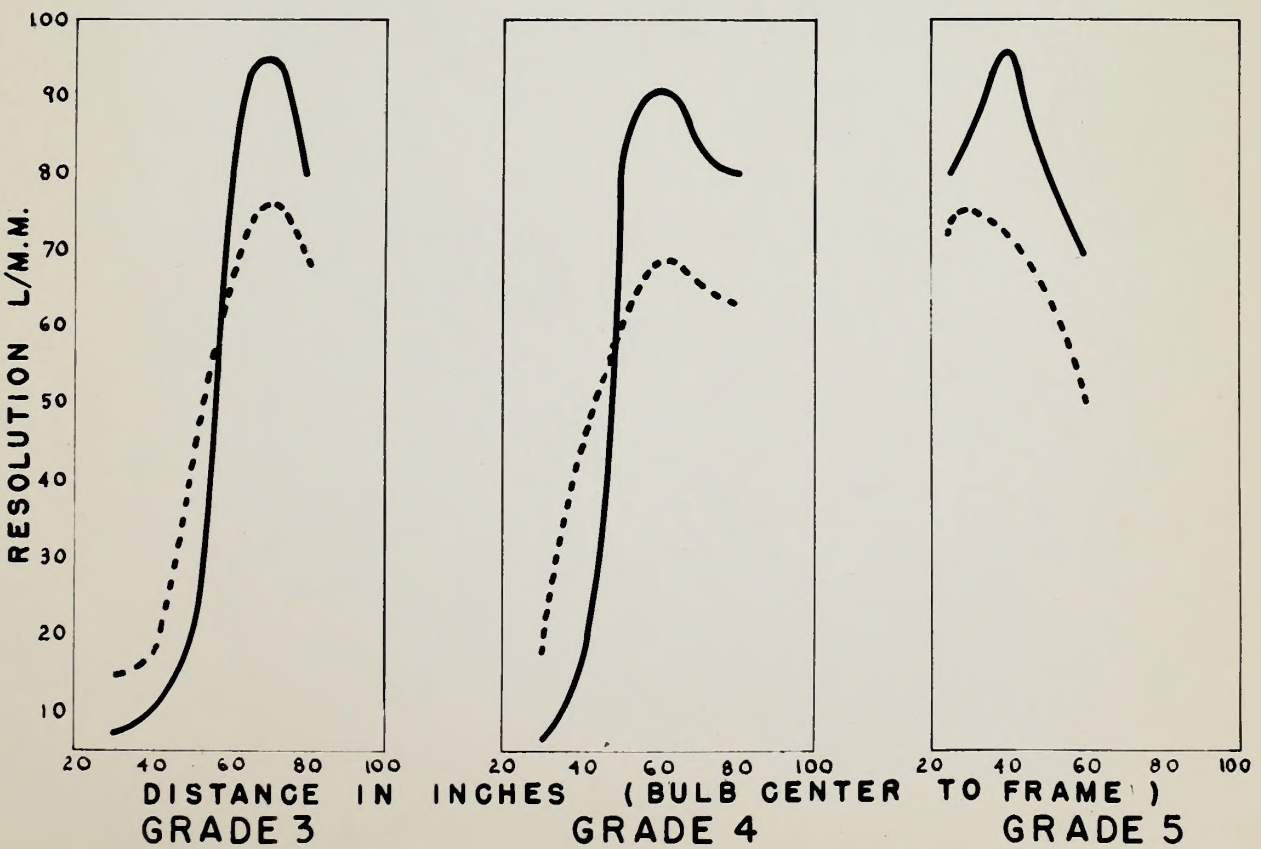
F-4	F-5
30" - 16.29	25" - 72.59
40" - 45.20	30" - 72.59
50" - 63.49	33" - 75.86
55" - 68.26	36" - 71.74
60" - 63.49	40" - 71.74
65" - 63.49	50" - 71.74
70" - 63.49	60" - 50.39
80" - 63.49	

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

RESOLUTION–DISTANCE CHARTS

CURVES OF TESTS ON KODABROMIDE GLOSSY PAPER, GRADES 1-5, WITH EDGERTON UNIT.





Azo Paper (Glossy Surface) (Reflection)

(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (l/mm)
0	3"	37.94
	5"	42.60
	7"	53.67
	8"	57.79
	9"	67.62
	10"	71.74
	11"	71.74
	12"	73.80
	13"	75.87
	14"	75.87
	15"	76.94
	18"	79.99
	19"	85.19
	20"	85.19
	22"	81.06
1	3"	15.05
	5"	15.87
	7"	26.84
	8"	28.81
	9"	31.75
	10"	45.20
	11"	50.39
	12"	60.22
	13"	67.62
	14"	71.74
	15"	73.80
	18"	78.46
	21"	78.46
	22"	78.46
	24"	85.19
	25"	75.87
2	3"	31.75
	6"	37.94
	7"	40.00
	8"	45.20
	9"	51.07
	10"	57.79
	11"	63.49
	13"	73.49
	14"	75.86
	16"	77.93
	17"	81.06
	18"	82.59
	20"	82.59
	21"	95.58
	22"	93.85
	23"	79.99
	24"	79.99

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

A&O Paper (Glossy Surface) (Reflection)

(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (L/mm)
0	3"	37.94
	5"	42.60
	7"	53.67
	8"	57.79
	9"	67.62
	10"	71.74
	11"	71.74
	12"	73.80
	13"	75.87
	14"	75.87
	15"	76.94
	18"	79.99
	19"	85.19
	20"	85.19
	22"	81.00
1	3"	15.05
	5"	15.87
	7"	26.84
	8"	28.81
	9"	31.75
	10"	45.20
	11"	50.29
	12"	60.22
	13"	67.02
	14"	71.74
	15"	73.80
	18"	78.46
	21"	78.46
	22"	78.46
	24"	85.19
	25"	75.87
2	3"	31.75
	6"	37.94
	7"	40.00
	8"	45.20
	9"	51.07
	10"	57.79
	11"	63.49
	13"	73.49
	14"	75.80
	15"	77.93
	17"	81.06
	18"	82.59
	20"	82.59
	21"	95.38
	22"	93.85
	23"	73.33

Note: The distances referred to above are the distances from the edge on Unit to the printing frame during the exposure.

Azo Paper (Glossy Surface) (Reflection)

(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (l/mm)
3	2"	67.62
	3"	85.19
	5"	79.99
	6"	72.59
	9"	71.74
	11"	71.42
	14"	70.52
	16"	69.68
	17"	67.62
	18"	60.22
4	2"	40.00
	3"	79.99
	5"	71.74
	6"	71.74
	7"	63.49
	8"	60.22
	9"	59.12
	10"	58.25
	11"	57.79
	12"	55.76
	13"	55.76
	14"	53.66
	15"	53.66
	18"	51.07
	25"	50.39
	30"	50.39
	35"	46.93
5	3"	12.60
	5"	16.70
	6"	23.47
	7"	34.50
	9"	90.39
	10"	95.58
	11"	90.39
	12"	85.19
	13"	83.45
	14"	79.99
	15"	79.99
	18"	79.99
	19"	79.99
	20"	74.49
	21"	63.49

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Azo Paper (Glossy Surface) (Reflection)

(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (L/mm)
5	2"	67.82
	3"	85.19
	5"	79.99
	6"	72.59
	9"	71.74
	11"	71.42
	12"	70.52
	16"	69.68
	17"	67.62
	18"	60.22
4	2"	40.00
	3"	79.99
	5"	71.74
	6"	71.74
	7"	63.49
	8"	60.12
	9"	57.12
	10"	56.45
	11"	57.79
	12"	55.10
	13"	53.10
	14"	52.66
	15"	53.50
	16"	51.07
	25"	50.39
	30"	50.39
	35"	46.93
3	2"	42.00
	5"	42.70
	6"	43.47
	7"	34.50
	9"	30.39
	10"	95.58
	11"	30.39
	12"	85.19
	13"	39.43
	14"	79.99
	15"	79.99
	16"	79.99
	17"	79.99
	20"	74.43
	21"	63.49

Note: The dists. were referred to above are the distance from the Exterion Unit to the printing frame during the exposure.

Azo Paper (Glossy) (Transmission)

(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (1/mm)
0	3"	60.22
	5"	64.34
	7"	70.11
	8"	71.74
	9"	71.74
	10"	75.87
	11"	79.99
	12"	79.99
	13"	79.99
	14"	79.99
	15"	79.99
	18"	79.99
	19"	79.99
	20"	85.19
	21"	79.99
	22"	71.74
1	3"	34.24
	5"	40.00
	7"	50.39
	8"	52.03
	9"	60.22
	10"	67.62
	11"	69.68
	12"	71.74
	13"	73.81
	14"	75.87
	15"	79.99
	18"	82.59
	21"	82.59
	22"	85.19
	24"	82.59
	25"	79.99
2	3"	40.54
	6"	47.79
	8"	50.39
	9"	53.67
	10"	58.47
	11"	59.44
	13"	60.22
	14"	60.22
	15"	63.49
	16"	75.87
	17"	79.99
	18"	85.19
	19"	90.39
	20"	85.19
	21"	83.13
	22"	80.53
	23"	79.99
	24"	76.94

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Agfa Paper (Glossy) (Transmission)

(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (l/mm)
0	3"	60.22
	5"	64.34
	7"	70.11
	8"	71.74
	9"	74.14
	10"	75.87
	11"	79.39
	12"	79.99
	13"	79.99
	14"	79.39
	15"	79.99
	16"	79.99
	17"	79.99
	20"	85.19
	21"	79.99
	22"	71.74
1	3"	34.64
	5"	40.00
	7"	50.39
	8"	54.03
	9"	60.22
	10"	67.62
	11"	69.68
	12"	71.74
	13"	73.81
	14"	75.87
	15"	77.93
	16"	80.39
	17"	82.54
	20"	85.19
	21"	82.39
	22"	79.39
2	3"	40.34
	5"	47.79
	8"	50.39
	9"	53.67
	10"	56.47
	11"	59.44
	13"	60.22
	14"	60.22
	15"	63.29
	16"	75.87
	17"	79.99
	18"	85.19
	19"	90.39
	20"	85.19
	21"	85.19
	22"	80.82
	24"	76.34

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Azo Paper (Glossy) (Transmission) (Continued)

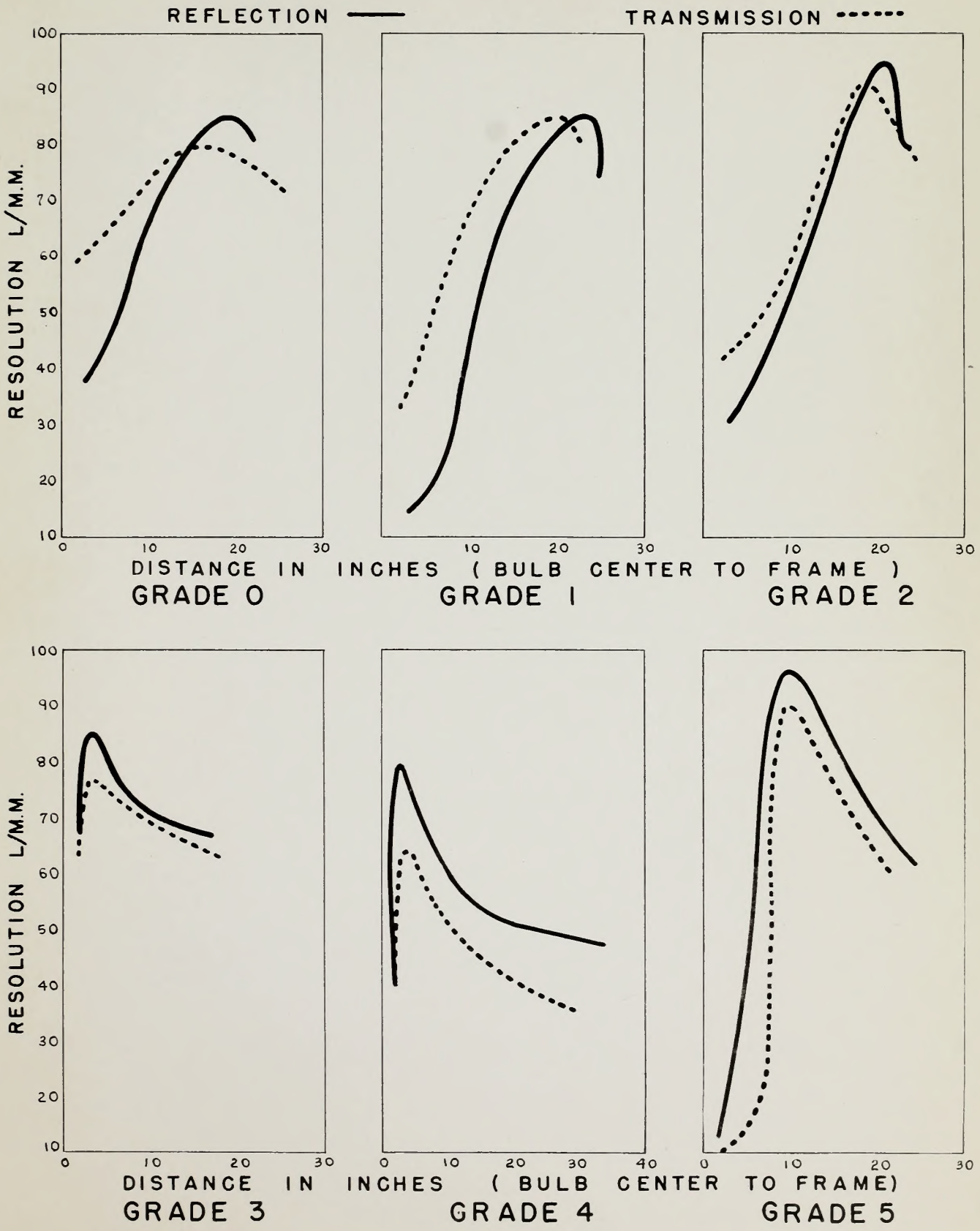
(Average of 4 observers)

Paper Grade	Distance (Inches)	Resolution (1/mm)
3	2"	63.49
	3"	75.87
	6"	71.74
	9"	69.68
	15"	67.62
	16"	63.49
	17"	63.49
	18"	63.49
4	2"	40.00
	3"	63.49
	6"	60.22
	7"	53.67
	8"	52.03
	9"	50.39
	10"	50.39
	11"	45.20
	12"	42.60
	13"	41.30
	14"	40.00
	15"	38.48
	18"	37.94
	30"	36.30
	35"	32.18
5	3"	8.46
	5"	13.42
	6"	17.38
	7"	69.68
	8"	75.87
	9"	79.99
	10"	90.39
	11"	85.19
	12"	79.99
	13"	79.99
	14"	77.93
	15"	71.74
	18"	63.49
	19"	63.49
	20"	63.49
	21"	60.22

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

RESOLUTION-DISTANCE CHARTS

CURVES OF TESTS ON AZO GLOSSY PAPER, GRADES 0–5, WITH EDGERTON UNIT.



Kodabromide (Semi-Matte)(Reflection)

(Average of 4 observers)

Resolution in l/mm

E-1	E-2	E-3	E-4
15" - 65.19	50" - 50.39	40" - 74.43	40" - 47.83
17" - 69.86	70" - 63.49	50" - 79.99	50" - 74.43
19" - 79.99	72" - 72.59	53" - 90.39	55" - 77.21
20" -108.68	74" - 79.99	55" - 95.58	60" - 79.99
23" -100.78	76" - 85.19	56" -100.78	65" - 79.99
28" - 93.85	77" - 95.58	57" - 95.58	70" - 79.99
30" - 93.85	78" -100.78	60" - 79.99	71" - 95.58
40" - 86.92	80" - 86.92	70" - 79.99	72" - 90.39
43" - 79.99	86" - 79.99	75" - 79.99	73" - 87.78
46" - 79.99	90" - 79.99	80" - 79.99	74" - 87.78
50" - 79.99	92" - 77.21	85" - 67.62	76" - 79.99
53" - 77.21	94" - 74.43		80" - 71.74
56" - 77.21	96" - 71.74		
60" - 74.43			
70" - 63.49			
80" - 50.39			

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Kodabromide (Semi-Matte)(Reflection)

(Average of 4 observers)

Resolution in l/mm

E-1	E-2	E-3	E-4
15" - 65.19	50" - 50.39	40" - 74.43	40" - 47.83
17" - 69.86	70" - 63.49	50" - 79.99	50" - 74.43
19" - 79.99	72" - 72.59	53" - 90.39	55" - 77.21
20" -108.68	74" - 79.99	55" - 95.58	60" - 79.99
23" -100.78	76" - 85.19	56" -100.78	65" - 79.99
28" - 93.85	77" - 95.58	57" - 95.58	70" - 79.99
30" - 93.85	78" -100.13	60" - 79.99	71" - 95.58
40" - 86.92	80" - 86.92	70" - 79.99	72" - 90.39
43" - 79.99	86" - 79.99	75" - 79.99	73" - 87.78
46" - 79.99	90" - 79.99	80" - 79.99	74" - 87.78
50" - 79.99	92" - 77.21	85" - 67.62	76" - 79.99
53" - 77.21	94" - 74.43		80" - 71.74
56" - 77.21	96" - 71.74		
60" - 74.43			
70" - 63.49			
80" - 50.39			

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Kodabromide (matte) (Transmission)

(Average of 4 observers)

Resolution in 1/mm

E-1	E-2	E-3	E-4
15" - 53.67	50" - 67.62	40" - 90.39	40" - 79.99
17" - 67.62	70" - 71.74	50" -100.78	50" - 79.99
19" - 75.87	72" - 75.86	53" - 85.19	55" - 79.99
20" - 19.99	74" - 79.99	54" - 85.19	60" - 79.99
23" - 90.39	76" - 85.19	55" - 79.99	65" - 79.99
26" -100.78	77" - 90.38	56" - 79.99	71" - 79.99
28" - 86.26	78" -100.78	57" - 79.99	72" - 85.19
30" - 83.13	79" - 95.58	60" - 79.99	74" - 95.58
40" - 79.99	86" - 90.39	65" - 75.87	75" - 79.99
43" - 75.87	88" - 90.39	70" - 71.74	76" - 79.99
50" - 71.74	90" - 79.99	75" - 63.49	80" - 75.87
53" - 69-68	92" - 79.99	80" - 63.49	
56" - 63.49	94" - 79.99	85" - 56.94	
60" - 53.67	96" - 63.49		
70" - 45.20			
80" - 37.94			

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Kodachrome (matte) (Transmission)

(Average of 4 observers)
Resolution in l/mm

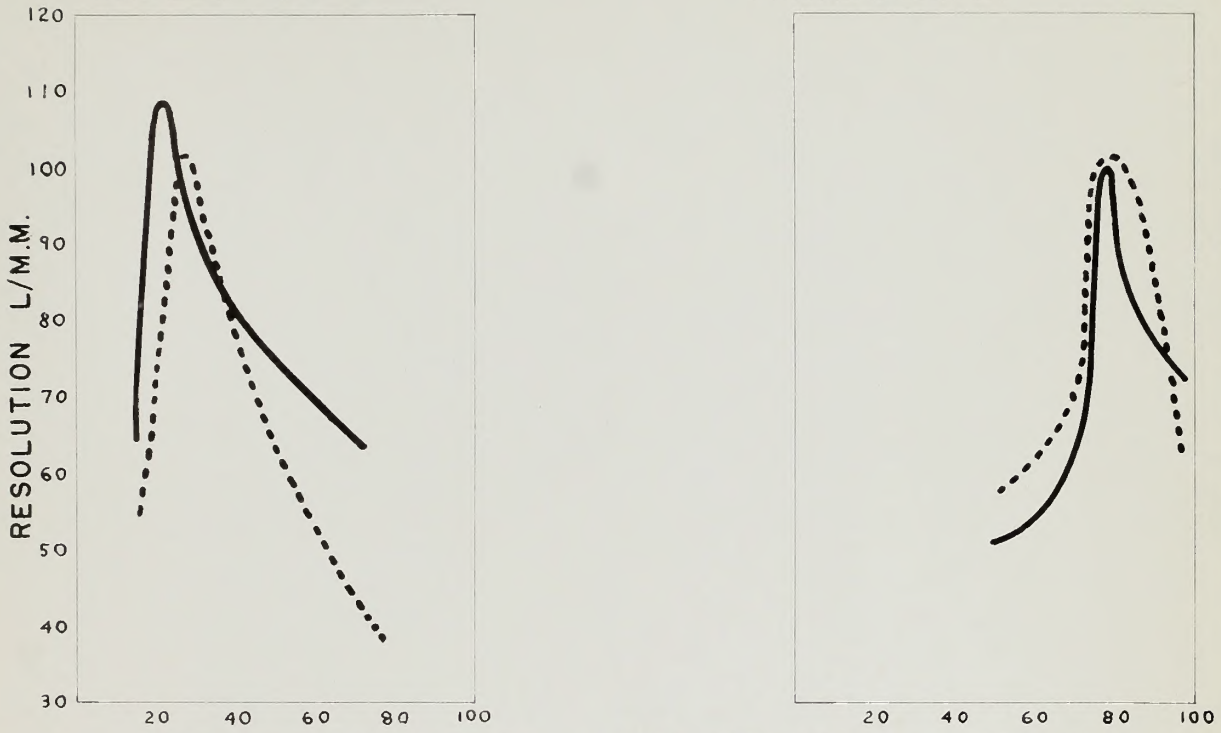
E-1	E-2	E-3	E-4
15" - 95.87	50" - 67.82	40" - 96.39	40" - 79.99
17" - 87.82	70" - 71.74	50" -100.78	50" - 79.99
19" - 79.87	72" - 79.86	53" - 85.19	55" - 79.99
20" - 19.99	74" - 79.99	54" - 85.19	60" - 79.99
23" - 90.39	76" - 85.19	55" - 73.99	65" - 79.99
26" -100.78	77" - 90.38	56" - 79.99	71" - 79.99
28" - 80.26	78" -100.78	57" - 79.99	72" - 85.19
30" - 83.15	79" - 95.58	60" - 79.99	74" - 95.58
40" - 79.99	80" - 90.39	65" - 75.87	75" - 77.99
43" - 75.37	38" - 90.39	70" - 71.74	76" - 79.99
50" - 71.74	90" - 79.99	75" - 69.49	80" - 75.87
53" - 69-03	92" - 79.99	80" - 63.49	
56" - 63.49	94" - 79.99	85" - 56.94	
60" - 59.87	96" - 63.49		
70" - 45.20			
80" - 37.94			

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

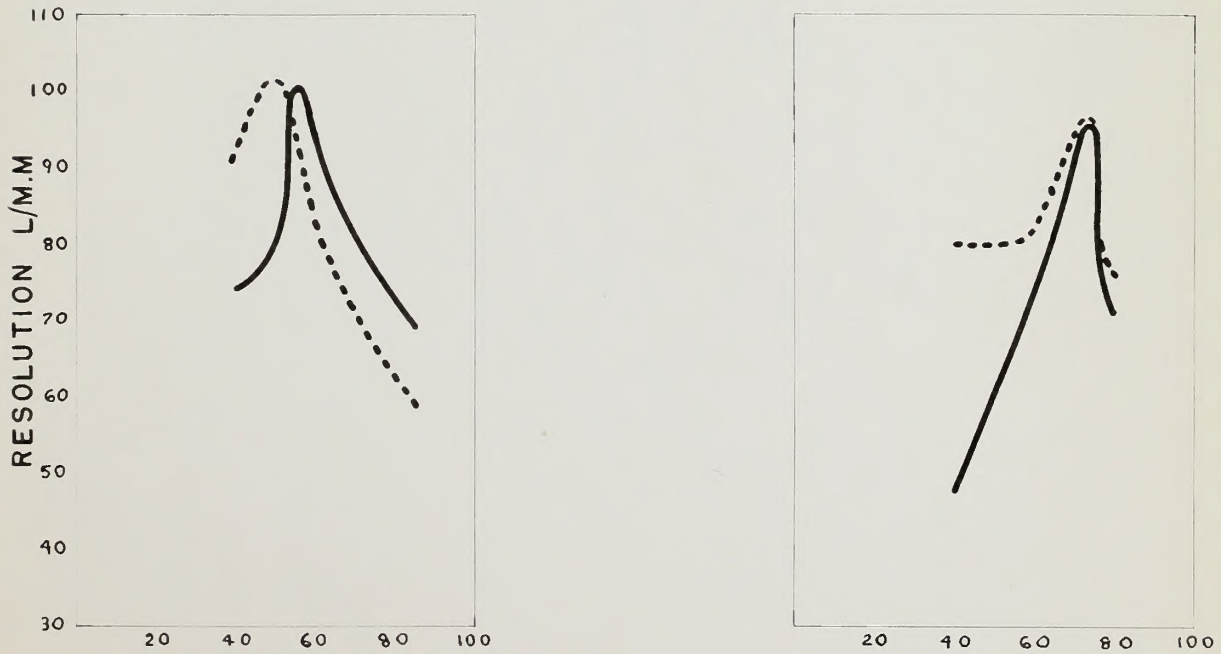
RESOLUTION-DISTANCE CHARTS

CURVES OF TESTS ON KODABROMIDE SEMI-MATTE PAPER, GRADES 1-4, WITH EDGERTON UNIT.

REFLECTION ——— TRANSMISSION - - - - -



GRADE 1 GRADE 2



GRADE 3 GRADE 4

Azo (Semi-Matte) (Reflection)

(Average of 4 observers)

Resolution in 1/mm

E-1	E-2	E-3
17" - 24.24	17" - 39.68	1" - 9.31
18" - 25.00	18" - 45.20	2" - 15.87
19" - 31.75	19" - 50.39	3" - 18.98
20" - 36.41	20" - 63.49	4" - 34.50
22" - 45.87	21" - 67.62	5" - 37.25
23" - 53.66	22" - 71.74	6" - 40.00
24" - 67.62	23" - 73.80	7" - 45.20
25" - 73.80	24" - 79.99	8" - 46.93
27" - 75.86	25" - 85.19	9" - 50.39
28" - 79.99	26" - 95.58	12" - 53.67
29" - 95.58	27" -100.78	13" - 60.22
30" - 90.38	28" - 98.18	14" - 67.62
31" - 85.19	29" - 98.18	15" - 75.87
	30" - 95.58	17" - 79.99
	31" - 90.39	19" - 85.19
		21" - 70.12

E-4	E-5
3" - 63.49	7" - 10.00
6" - 63.49	8" - 12.60
9" - 63.49	9" - 13.69
15" - 69.68	10" - 24.27
16" - 71.74	11" - 79.99
17" - 77.98	12" - 86.92
18" - 79.99	13" - 79.99
19" - 77.98	14" - 79.99
20" - 75.87	15" - 79.99
21" - 71.74	18" - 79.99
25" - 63.49	21" - 63.49
30" - 63.49	
35" - 50.39	

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Azo (Semi-Matte) (Reflection)

(Average of 4 observers)

Resolution in l/mm

E-1	E-2	E-3
17" - 24.24	17" - 39.68	1" - 9.31
18" - 25.00	18" - 45.20	2" - 15.87
19" - 31.75	19" - 50.39	3" - 18.98
20" - 36.11	20" - 63.49	4" - 34.50
22" - 45.87	21" - 67.62	5" - 37.25
23" - 53.66	22" - 71.74	6" - 40.00
24" - 57.62	23" - 73.80	7" - 45.20
25" - 73.80	24" - 79.99	8" - 46.93
27" - 75.80	25" - 85.19	9" - 50.39
28" - 79.99	26" - 95.58	12" - 53.67
29" - 95.58	27" -100.78	13" - 60.22
30" - 90.38	28" - 93.18	14" - 67.62
31" - 85.19	29" - 98.18	15" - 75.87
	30" - 95.58	17" - 79.99
	31" - 90.39	19" - 85.19
		21" - 70.12

E-4	E-5
3" - 63.49	7" - 10.00
6" - 63.49	8" - 12.90
9" - 63.49	9" - 13.69
15" - 69.68	10" - 24.27
16" - 71.74	11" - 79.99
17" - 77.98	12" - 86.32
18" - 79.99	13" - 79.99
19" - 77.98	14" - 79.99
20" - 75.37	15" - 79.99
21" - 71.74	18" - 79.99
25" - 63.49	21" - 63.49
30" - 63.49	
35" - 50.39	

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Azo (Matte) (Transmission)

(Average of 4 observers)

Resolution in l/mm

E-1	E-2	E-3
17" - 50.39	17" - 63.49	1" - 31.75
18" - 63.49	18" - 71.74	2" - 40.44
19" - 67.62	19" - 71.74	3" - 56.94
20" - 79.99	20" - 79.99	4" - 63.49
22" - 85.19	21" -102.13	5" - 63.49
23" - 90.38	23" - 90.38	6" - 75.87
24" - 95.58	24" - 85.19	7" - 85.19
25" -107.33	26" - 85.19	8" - 63.49
26" - 90.38	27" - 85.19	13" - 63.49
28" - 85.19	28" - 79.99	14" - 63.49
29" - 82.59	29" - 79.99	15" - 63.49
30" - 79.99	30" - 79.99	17" - 61.86
31" - 79.99	31" - 75.87	18" - 57.62
		19" - 57.00
		20" - 53.47
		21" - 50.39

E-4	E-5
3" - 63.49	7" - 12.60
4" - 63.49	8" - 15.05
5" - 63.49	9" - 85.19
6" - 79.99	10" - 90.39
9" - 50.39	11" - 95.58
12" - 47.80	12" -100.78
15" - 45.54	13" - 90.39
17" - 42.60	14" - 85.19
18" - 42.60	15" - 79.99
21" - 40.00	18" - 71.74
25" - 38.21	21" - 63.49
30" - 37.94	
35" - 35.88	

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Apo (Matte) (Transmission)

(Average of 4 observers)

Resolution in l/mm

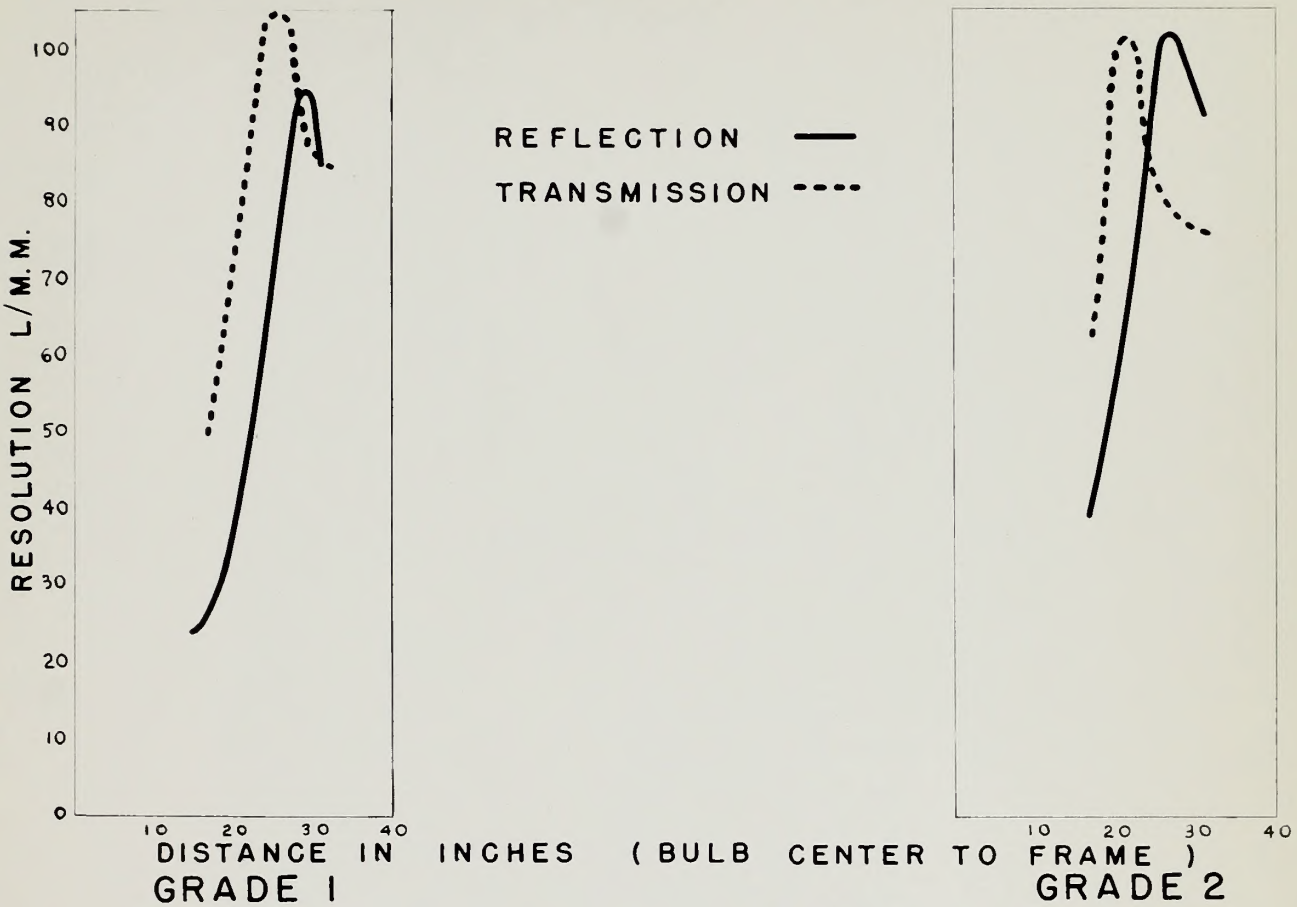
E-1	E-2	E-3
17" - 50.39	17" - 63.49	1" - 71.75
18" - 63.49	18" - 71.74	2" - 40.44
19" - 67.02	19" - 71.74	3" - 56.94
20" - 79.99	20" - 79.99	4" - 63.49
22" - 85.19	21" -102.13	5" - 63.49
23" - 90.38	23" - 90.38	6" - 75.87
24" - 95.58	22" - 85.19	7" - 85.19
25" -107.33	26" - 63.49	8" - 53.49
26" - 90.38	27" - 85.19	13" - 63.49
28" - 85.19	28" - 79.99	14" - 63.49
29" - 82.59	24" - 79.99	15" - 63.49
30" - 79.99	30" - 79.99	17" - 61.86
31" - 79.99	31" - 75.87	18" - 57.02
		19" - 57.00
		20" - 53.17
		21" - 50.39

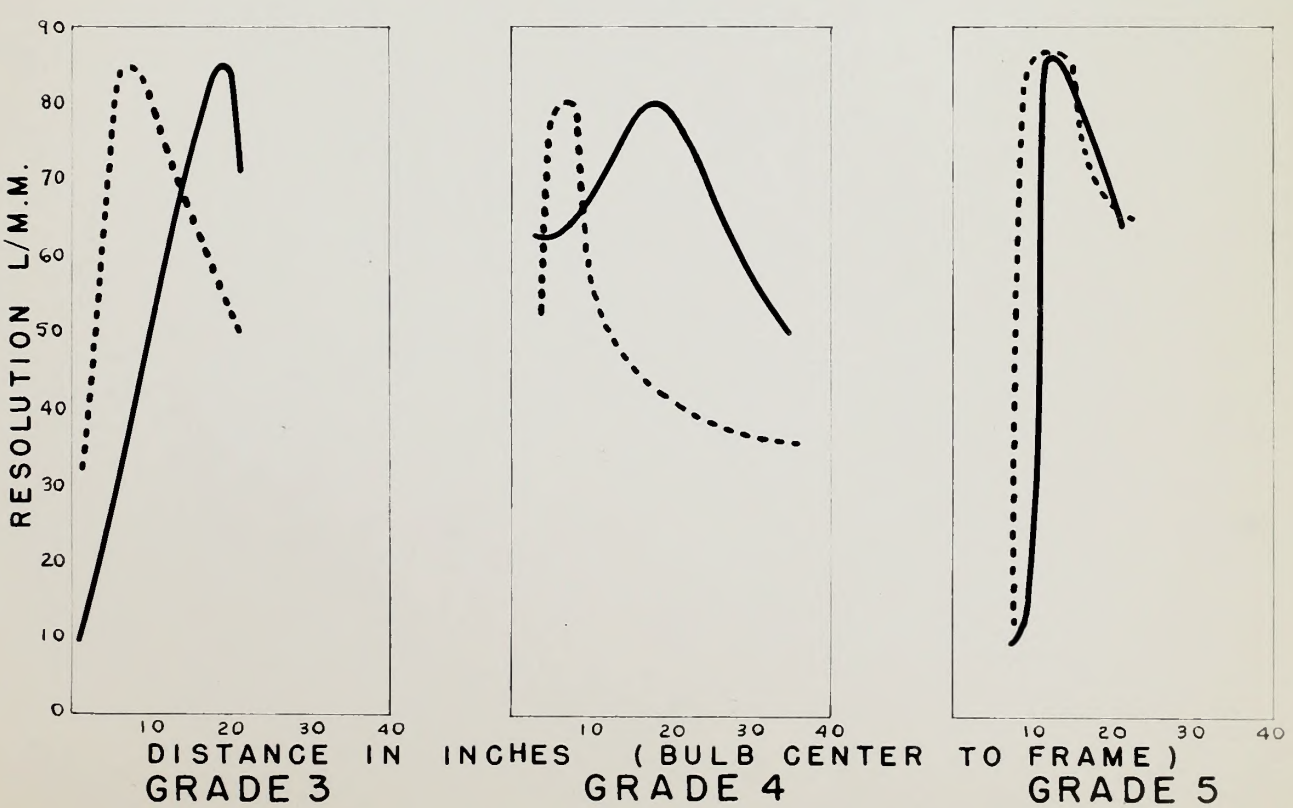
E-4	E-5
3" - 63.49	7" - 12.50
4" - 63.49	8" - 15.05
5" - 63.49	9" - 25.19
6" - 79.99	10" - 30.39
9" - 50.39	11" - 35.58
12" - 47.80	12" -100.78
15" - 45.54	13" - 90.39
17" - 42.60	14" - 85.19
18" - 42.50	15" - 79.99
21" - 40.00	16" - 71.74
25" - 38.21	21" - 63.49
30" - 37.94	
35" - 35.88	

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

RESOLUTION–DISTANCE CHARTS

CURVES OF TESTS ON AZO SEMI – MATTE PAPER, GRADES 1-5, WITH EDGERTON UNIT.





Paper (Glossy)	Grade	Resolution (Reflection) (l/mm)
Azo	0	85.19
	1	85.19
	2	95.58
	3	85.19
	4	79.99
	5	95.58
Velox	0	79.99
	1	83.45
	2	86.92
	3	76.69
	4	73.39
	5	79.99
Kodabromide	-	-----
	1	90.39
	2	100.78
	3	95.58
	4	91.46
	5	95.58

Paper (Glossy)	Grade	Resolution (Transmission) (l/mm)
Azo	0	85.19
	1	85.19
	2	90.39
	3	75.86
	4	63.49
	5	90.39
Velox	0	63.49
	1	79.99
	2	79.99
	3	63.49
	4	63.49
	5	75.86
Kodabromide	-	-----
	1	79.99
	2	79.99
	3	75.86
	4	68.46
	5	75.86

Paper (Semi-matte)	Grade	Resolution (Reflection) (l/mm)
Azo	1	95.58
	2	100.78
	3	85.19
	4	79.99
	5	86.92
Kodabromide	1	108.68
	2	100.78
	3	100.78
	4	95.58

Paper (Semi-matte)	Grade	Resolution (Transmission) (l/mm)
Azo	1	107.33
	2	102.13
	3	85.19
	4	79.99
	5	100.78
Kodabromide	1	100.78
	2	100.78
	3	100.78
	4	95.58

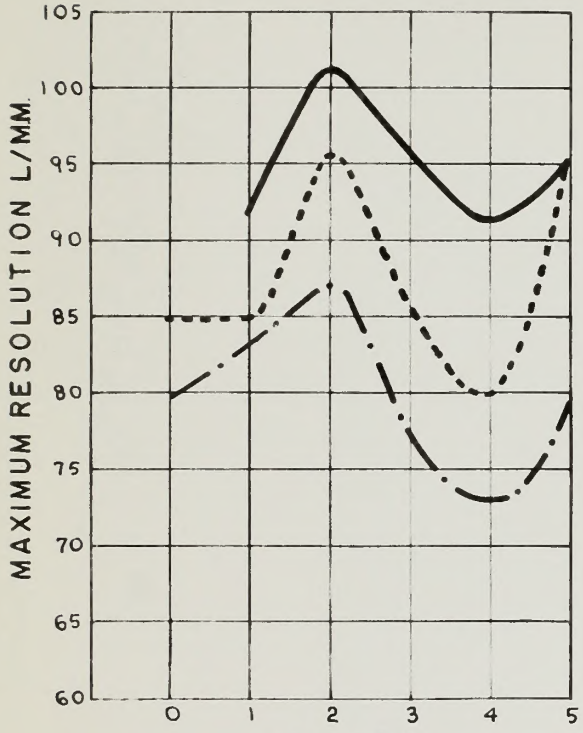
Paper (Semi-matte)	Grade	Resolution (Reflection) (L/mm)
Azo	1	95.98
	2	120.76
	3	85.14
	4	79.79
	5	80.94
Kodakromide	1	105.96
	2	100.78
	3	130.78
	4	95.98

Paper (Semi-matte)	Grade	Resolution (Transmission) (L/mm)
Azo	1	107.33
	2	102.13
	3	85.19
	4	79.89
	5	100.78
Kodakromide	1	100.78
	2	100.78
	3	100.78
	4	95.98

MAXIMUM RESOLUTION GRADE CHARTS

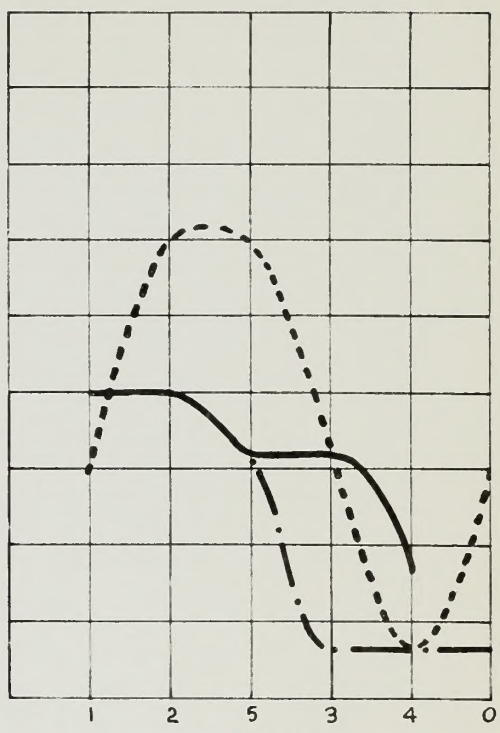
CURVES OF TESTS WITH EDGERTON UNIT

KODABROMIDE ——————
AZO ····· ····· ·····
VELOX —·—·—·—·—



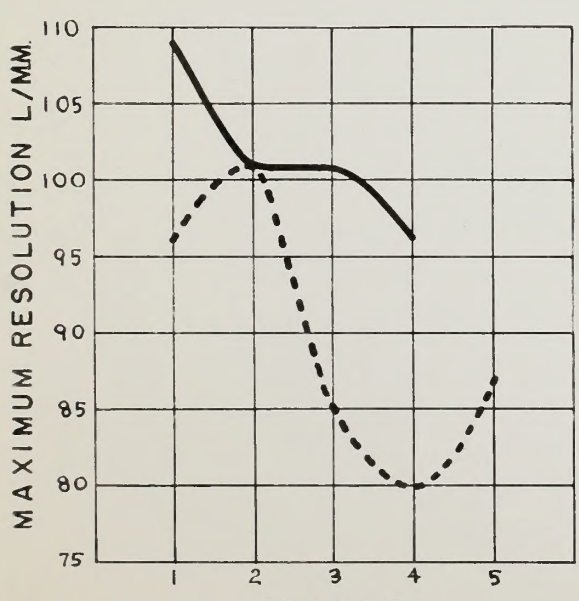
GLOSSY

READINGS BY REFLECTION



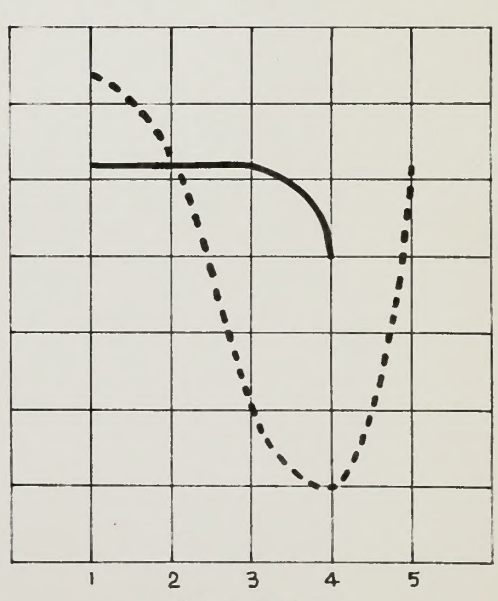
GLOSSY

READINGS BY TRANSMISSION



SEMI-MATTE

READINGS BY REFLECTION



SEMI-MATTE

READINGS BY TRANSMISSION

D. Conclusions:

1. Bromide paper will give higher reflection resolution than chloride under similar circumstances.
   a. Kodabromide - 94.76
   b. Azo - 87.79
   c. Velox - 80.07
2. Reflection resolution will give a higher maximum than transmission resolution on glossy paper.
3. Semi-matte surface papers in the case of both chloride and bromide give an average higher resolution value than glossy surfaces.
   a. Azo - (reflection)

Glossy	Semi-matte	
87.79	89.49	(Average)

   b. Kodabromide - (reflection)

Glossy	Semi-matte	
94.58	101.46	(average)

4. Grade 2 paper gives the highest average resolution value.

Grade	Resolution	No; of Values Used
2	93.81	10
1	91.66	10
3	84.46	10
5	86.97	8
4	79.14	10
0	78.47	4

5. Azo paper will give higher resolution than Velox under similar conditions.

	Reflection	Transmission
Azo -	87.79	81.59
Velox -	80.07	71.05

D. Conclusions:

1. Bromide paper will give higher reflection resolution than chloride under similar circumstances.
   a. Kodabromide - 94.76
   b. Azo - 87.79
   c. Velox - 80.07
2. Reflection resolution will give a higher maximum than transmission resolution on glossy paper.
3. Semi-matte surface papers in the case of both chloride and bromide give an average higher resolution value than glossy surfaces.
   a. Azo - (reflection)

Glossy	Semi-matte	
87.79	89.49	(average)

   b. Kodabromide - (reflection)

Glossy	Semi-matte	
94.56	101.46	(average)

4. Grade 2 paper gives the highest average resolution value.

Grade	Resolution	No. of Values Used
2	93.81	10
1	91.66	10
3	84.46	10
5	80.97	8
4	79.14	10
0	75.47	4

5. Azo paper will give higher resolution than Velox under similar conditions.

	Reflection	Transmission
Azo -	87.79	81.59
Velox -	80.07	71.05

6. Azo paper gives higher transmission resolution than Kodabromide on glossy surface.

   Azo - 81.59 Kodabromide - 76.03

7. Bromide papers show a larger decrease in transmission readings on glossy prints than chloride papers.

	Reflection	Transmission
Azo -	87.79	81.59
Kodabromide -	94.58	76.03
Velox -	80.07	71.05

8. Chloride paper shows higher resolution with semi-matte surface by transmission than by reflection.

   Azo - 95.08 Transmission

   89.49 Reflection

CHAPTER III

A. Statement of the Problem:

1. Investigation of Print Resolution of Varigam Paper

B. Experimental Procedure:

1. Materials

a) Test Object:

The negative used in this work was a U.S. Army test object of infinite contrast and maximum resolution of 200 l/mm. (See Frontispiece)

b) Positive Material:

The positive material used in this test was Defender Varigam, glossy, smooth, white, with appropriate wratten filters to vary contrast.

2. Processing Conditions

(See Chapter I)

CHAPTER III

A. Statement of the Problem:

1. Investigation of Print Resolution of Various Paper

B. Experimental Procedure:

1. Materials

a) Test Object:

The negative used in this work was a U.S. Army test object of infinite contrast and maximum resolution of 200 l/mm. (See Frontispiece)

b) Positive Material:

The positive material used in this test was Defender Varigam, glossy, smooth, white, with appropriate written titers to very contrast.

2. Processing Conditions

(See Chapter I)

C. Tables of Results

Filter No:	Distance (Inches)	Resolution (Reflection) (l/mm)
None	5"	14.78
	10"	25.20
	20"	79.99
	25"	100.78
	30"	113.88
	33"	153.24
	34"	146.94
	36"	145.24
	37"	135.23
CC44	5"	10.14
	10"	18.62
	20"	79.99
	23"	93.85
	25"	102.58
	27"	107.33
	28"	113.17
	29"	118.25
	30"	122.13
	31"	126.98
	32"	135.23
	35"	107.33
78AA	5"	63.49
	10"	79.99
	18"	102.13
	19"	107.33
	20"	120.43
	21"	113.88
	22"	107.33
3	1"	24.27
	2"	44.18
	3"	50.39
	4"	59.12
	5"	79.99
	7"	63.49
	8"	63.49
	9"	63.49
	10"	63.49
	20"	59.12

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Filter No:	Distance (Inches)	Resolution (Reflection) (l/mm)
None	5"	14.78
	10"	25.20
	20"	79.99
	25"	100.78
	30"	113.88
	33"	153.24
	34"	146.94
	36"	145.24
	37"	135.29
0044	5"	10.14
	10"	16.02
	20"	79.99
	23"	93.85
	25"	102.56
	27"	107.33
	29"	113.17
	29"	116.25
	30"	122.13
	31"	136.98
	32"	135.23
	33"	107.33
7AAA	5"	03.49
	10"	79.99
	18"	102.13
	19"	107.33
	20"	120.43
	21"	113.85
	22"	107.33
3	1"	63.27
	2"	44.16
	3"	50.39
	4"	54.12
	5"	79.39
	7"	03.49
	8"	02.49
	9"	03.49
	10"	03.47
	20"	59.12

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Filter No:	Distance (Inches)	Resolution (Reflection) (l/mm)
7	1" (2 flashes)	24.27
	1"	29.57
	2"	46.93
	3"	50.39
	5"	63.49
	9"	67.62
	10"	68.99
	12"	71.74
	15"	75.87
	20"	50.39
12	1" (3 flashes)	23.45
	1" (2 flashes)	34.50
	1"	40.00
	2"	50.39
	3"	54.76
	5"	50.39
	10"	46.92
	20"	43.46

Filter No:	Distance (Inches)	Resolution (Transmission) (l/mm)
None	5"	15.87
	10"	40.00
	20"	86.92
	25"	90.39
	30"	107.33
	33"	110.61
	34"	113.88
	35"	120.43
	36"	113.88
	37"	107.33
CC44	5"	12.60
	10"	50.39
	20"	86.92
	23"	93.85
	25"	102.58
	27"	113.88
	28"	118.25
	29"	120.43
	30"	113.88
	31"	110.33
	32"	107.33
	35"	107.33
78AA	5"	68.99
	10"	79.99
	18"	90.39
	19"	95.58
	20"	100.78
	21"	107.33
	22"	100.78
3	1"	43.46
	2"	50.39
	3"	54.76
	4"	59.12
	5"	63.49
	7"	63.49
	8"	63.49
	9"	63.49
	10"	60.22
	20"	50.39

Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Filter No:	Distance (Inches)	Resolution (Transmission) (l/mm)
7	1" (2 flashes)	25.20
	1"	37.25
	2"	40.00
	3"	50.39
	5"	51.29
	9"	63.49
	10"	63.49
	12"	60.22
	15"	50.39
	20"	46.93
12	1" (3 flashes)	20.00
	1" (2 flashes)	25.20
	1"	31.75
	2"	34.65
	3"	40.71
	5"	37.25
	10"	34.17
	20"	31.75

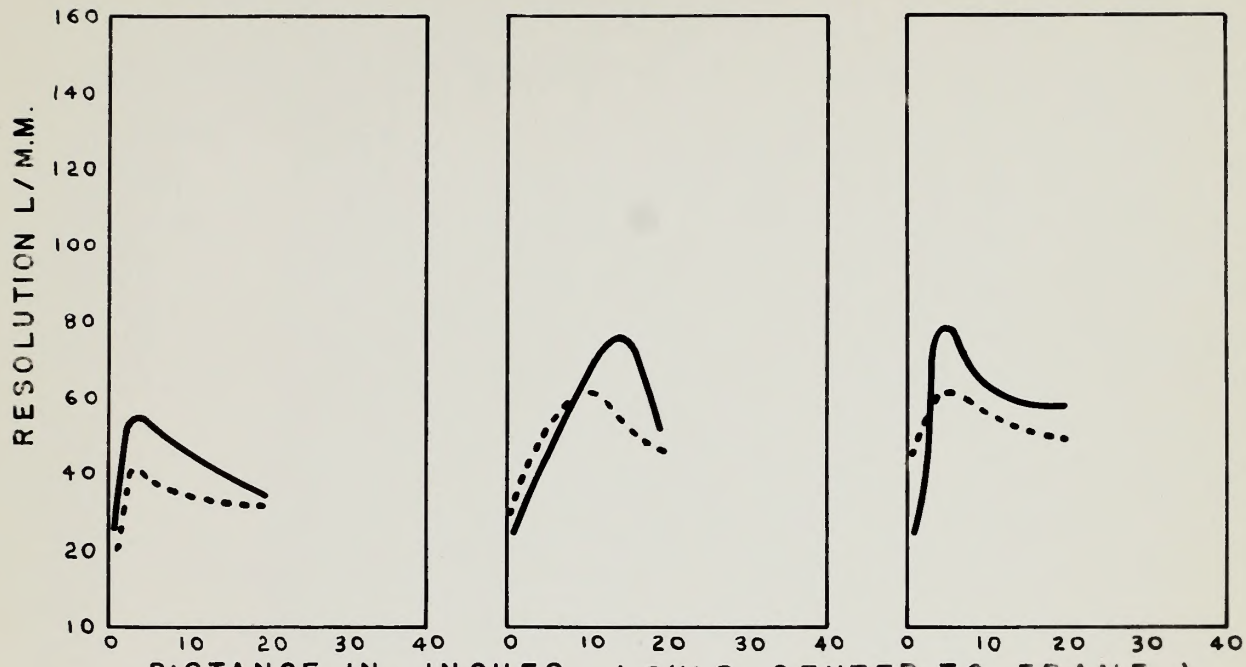
Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

Filter No:	Distance (Inches)	Resolution (Frequency/mm)
7	1" (2 flashes)	25.20
	1"	37.25
	2"	40.00
	3"	50.39
	5"	51.29
	9"	65.79
	10"	63.49
	12"	60.22
	15"	50.39
	20"	45.93
12	1" (3 flashes)	20.00
	1" (2 flashes)	25.20
	1"	31.75
	2"	34.65
	3"	40.71
	5"	37.25
	10"	34.17
	20"	31.75

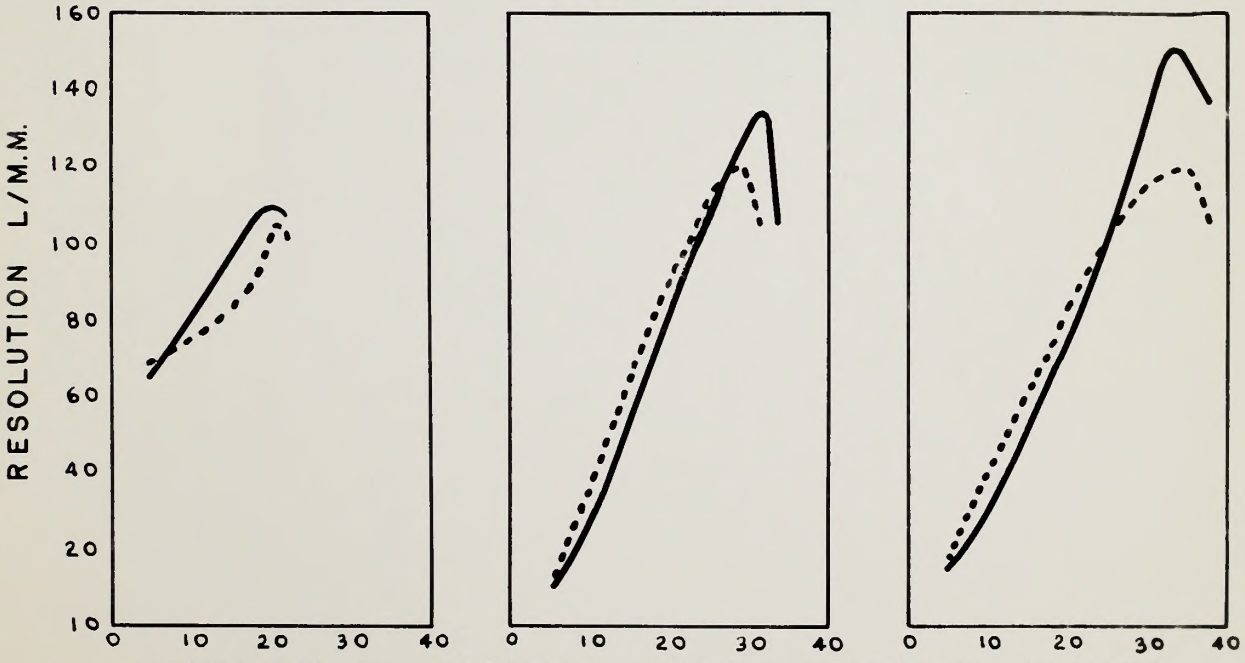
Note: The distances referred to above are the distances from the Edgerton Unit to the printing frame during the exposure.

RESOLUTION-DISTANCE CHARTS

CURVES OF TESTS ON VARIGAM GLOSSY PAPER, WITH WRATTEN FILTERS WITH EDGERTON UNIT.



REFLECTION ——
TRANSMISSION ----



Maximum Resolution
(1/mm)

Filter No:	Reflection	Transmission
None	153.24	120.43
CC44	135.23	120.43
78AA	120.43	107.33
3	79.99	63.49
7	75.87	63.49
12	54.76	40.71

D. Conclusions:

1. The resolution obtainable with Defender Varigam Paper far exceeds the highest value obtainable with the Eastman Papers that were used in the test.
   a). Varigam - - - - - 153.24 1/mm (Reflection)
   b). Kodabromide - - - 108.68 1/mm (Reflection)
2. Transmission resolution on the Varigam is higher than transmission resolution on Kodak Paper.
   a). Varigam - - - - - 120.43
   b). Azo (Semi-matte)- 107.33

Maximum Resolution

(l/mm)

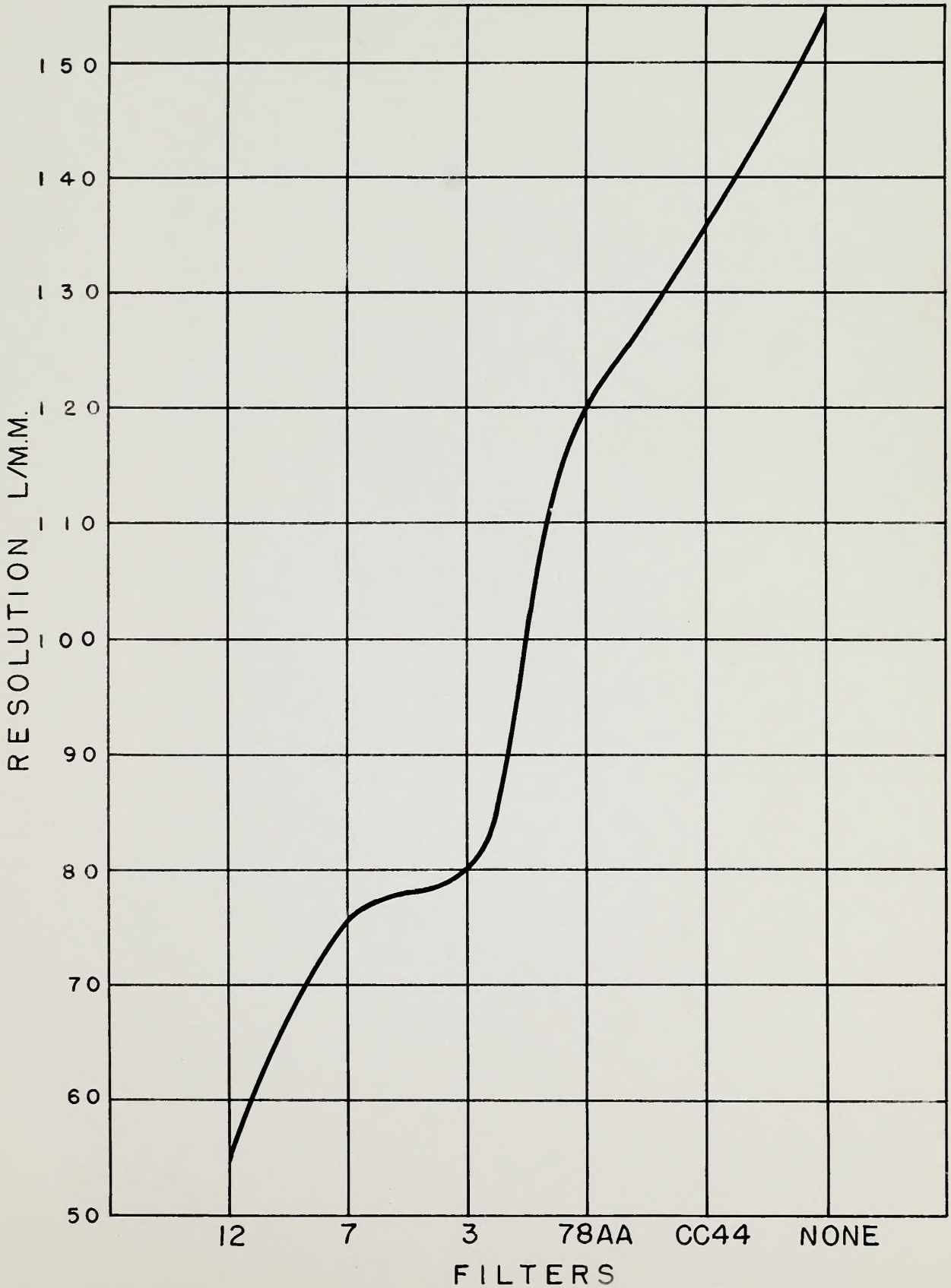
Filter No:	Reflection	Transmission
None	153.24	120.43
CC44	139.29	120.43
78AA	120.43	107.33
3	79.99	63.49
7	75.87	63.49
12	64.76	40.71

D. Conclusions:

1. The resolution obtainable with Defender Vertigam Paper far exceeds the highest value obtainable with the Eastman Papers that were used in the test.
   a). Vertigam - - - - - 153.24 l/mm (Reflection)
   b). Kodagronite - - - 108.68 l/mm (Reflection)
2. Transmission resolution on the Vertigam is higher than transmission resolution on Kodak Paper.
   a). Vertigam - - - - - 120.43
   b). Azo (Semi-matte)- 107.33

MAXIMUM RESOLUTION — FILTER CHART

CURVE OF TESTS ON VARIGAM GLOSSY PAPER, WITH WRATTEN FILTERS WITH EDGERTON UNIT.



CHAPTER IV

A. Statement of the Problem:

1. The effect of pressure on the resolution of photographic printing paper.

B. Experimental Procedure:

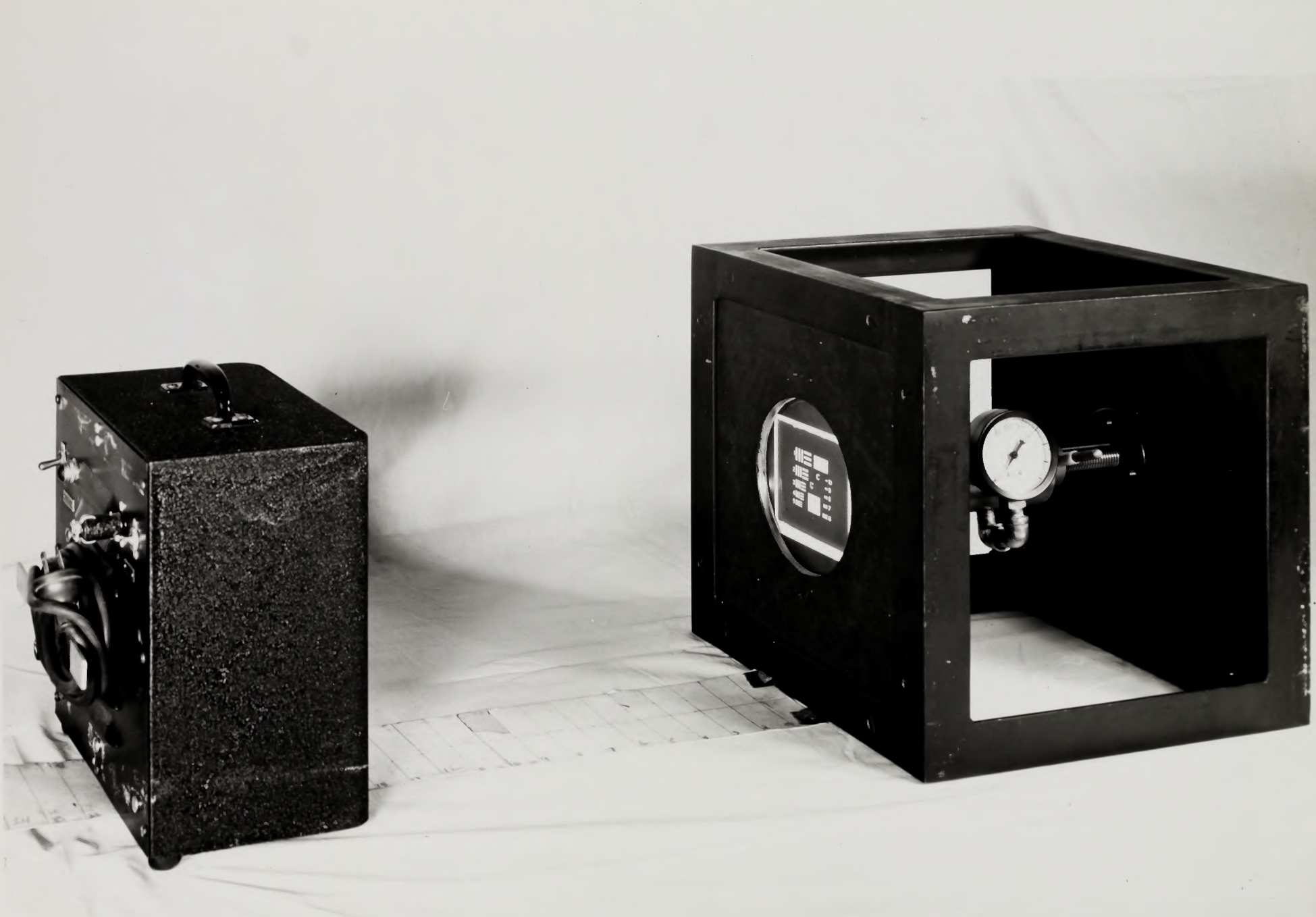
1. Materials

a) Test object:
(Same as described in Chapter I)

b) Positive Material:
The positive material used in this test was Velox, grade 2, glossy, white, smooth.

2. Processing Conditions

(See Chapter I)



C. Tables of Results

Exposure - Edgerton Flash Unit

Exposure Distance = 29"

Resolution (Reflection) (l/mm)	Force - lbs./sq. in.
50.39	1.67
63.49	3.33
79.99	5.00
79.99	6.67
79.99	8.33
79.99	10.00
79.99	11.67
79.99	13.33
79.99	15.00
79.99	16.67

D. Conclusions:

1. The maximum resolution under a given set of conditions will be attained at a pressure of 5 lbs./sq. in. Further increases in pressure will not affect the maximum resolution.

Exposure - Sequetron Flash Unit

Exposure Distance = 29"

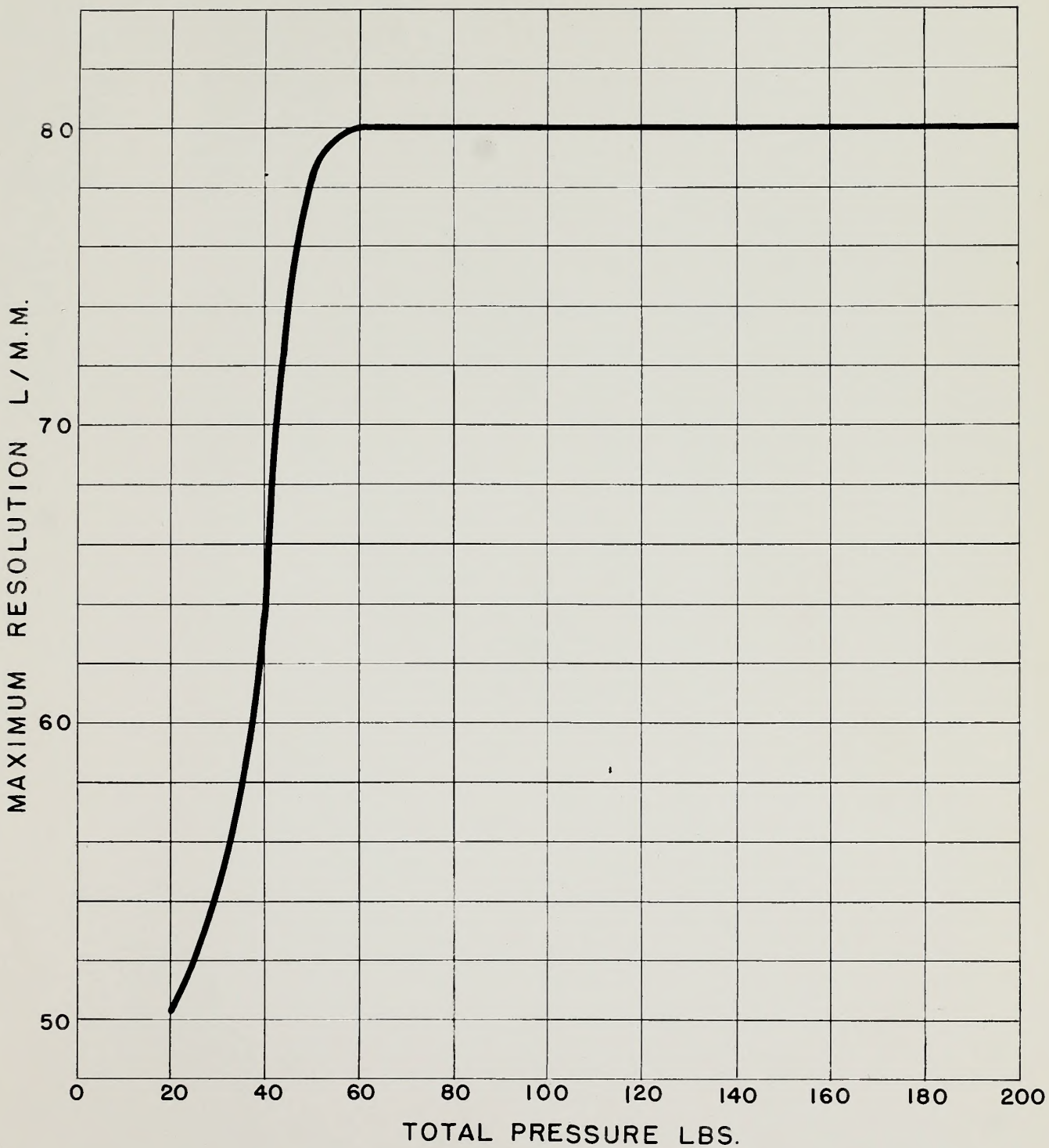
Force - lbs./sq. in.	Resolution (Reflection) (l/mm)
1.67	50.39
3.33	63.49
5.00	79.99
6.67	79.99
8.33	79.99
10.00	79.99
11.67	79.99
13.33	79.99
15.00	79.99
16.67	79.99

D. Conclusions:

1. The maximum resolution under a given set of conditions will be attained at a pressure of 5 lbs./sq. in. Further increases in pressure will not affect the maximum resolution.

MAXIMUM RESOLUTION-PRESSURE CHART

CURVE OF TESTS ON VELOX PAPER WITH LABORATORY PRESSURE PRINTING FRAME.



CONVERSION: PRESSURE LBS. TO PRESSURE LBS./SQ. INCH

DIVIDE TOTAL PRESSURE BY AREA (12 SQ. INCHES)

CHAPTER V

A. To Determine the Influence of Light and Eye Strain on Maximum Resolution:

We conclude that, except in cases of severe eye strain, eye tiredness has a negligible effect on the reading of maximum resolution. The most important factors in achieving high resolution seem to be the type and constancy of light on the targets read.

In this case, our experimental tests show that prints read on the viewing table through Fluorescent tubes and ground glass gave much higher resolution than did the same prints when read with ordinary room light. The total average resolution in lines per millimeter of sixteen prints read twice at the viewing table, transmission-by five observers was 41.56; while the total average resolution in lines per millimeter of the same sixteen prints read twice by five observers at their desks, reflection-with room light was 27.81.

Our tests indicate that bright morning light and "eye freshness" had virtually no effect on maximum resolution when prints were read at the desks of the observers. Prints read by morning light were found to have an average maximum resolution in lines per millimeter only .12 higher than the same prints read by late afternoon light at the desks after the five observers had been using their eyes in several hours of other close work.

The accompanying data will give the average of five readings for each print as it was read under the different light conditions.

CHAPTER V

A. To Determine the Influence of Light and Eye Strain on Maximum Resolution:

AVERAGE

MAXIMUM RESOLUTION READINGS

(5 Observers)

(Lines Per Millimeter)

Print No:	Monday A.M. At Viewer		Monday P.M. At Desks		Tuesday A.M. At Desks		Tuesday P.M. At Viewer	
	Transmission		Reflection		Reflection		Transmission	
36	28.48	30.11	6.30	6.30	7.39	6.37	33.74	33.74
37	42.60	42.60	21.30	20.27	27.39	21.56	53.01	53.01
38	17.60	16.57	6.30	6.30	6.70	6.44	19.77	19.12
39	56.94	56.94	50.39	50.39	46.23	48.85	55.63	60.87
40	60.22	60.22	50.39	50.39	50.93	53.01	55.63	55.63
41	45.20	47.79	31.75	31.75	29.47	31.05	50.39	50.39
42	22.94	22.94	7.94	7.53	8.95	8.02	26.51	25.47
43	45.20	45.20	31.75	31.75	30.08	29.04	50.39	50.39
44	37.94	35.88	15.05	13.42	18.73	17.25	40.43	40.00
45	22.94	21.30	8.97	7.94	8.44	8.02	29.13	27.82
46	33.81	33.81	15.87	15.87	16.73	15.91	38.35	38.35
47	50.39	50.39	50.39	50.39	48.31	48.31	50.39	50.39
48	50.39	53.67	50.39	50.39	48.31	50.39	50.39	50.39
49	42.60	40.00	40.00	42.60	40.00	40.00	40.00	40.00
50	35.88	37.94	22.60	21.57	24.91	24.26	42.08	42.08
51	50.39	48.47	35.88	35.88	33.74	37.04	50.39	50.39
Total	643.52	643.83	445.27	442.74	446.31	445.52	686.23	688.04
Average	40.22	40.24	27.83	27.67	27.89	27.85	42.89	43.00

AVERAGE

MAXIMUM RESOLUTION RESULTS

(5 Observers)

(Lines Per Millimeter)

Print No:	Monday A.M. At Viewer	Monday P.M. At Desks	Tuesday A.M. At Desks	Tuesday P.M. At Viewer
	Transmission	Reflection	Reflection	Transmission
36	28.48	30.11	7.39	33.74
37	42.00	42.60	37.39	53.01
38	17.60	16.57	6.44	19.77
39	56.04	56.94	48.85	60.87
40	60.22	60.22	53.01	55.65
41	45.20	47.79	31.05	50.39
42	22.94	22.94	7.39	26.31
43	45.20	45.20	31.05	50.39
44	37.94	39.68	16.73	40.00
45	22.94	21.50	7.94	29.15
46	33.81	35.81	16.73	36.35
47	50.39	50.39	46.31	50.39
48	50.39	53.67	50.39	50.39
49	42.00	40.00	40.00	40.00
50	33.68	37.94	24.41	42.08
51	50.39	48.47	37.04	50.39
AVERAGE:	40.22	42.74	27.89	43.00

B. Specific Comparison of Transmitted Light from Viewing Table and Reflected Light from Desk Lamp as Illumination on Resolution Targets.

Readings of prints of high contrast with desk lamp illumination and at the viewing table show that viewing table illumination gives a much higher resolution than desk lamp illumination. The brightness of the white background on high contrast prints causes a slight glare; the brightness makes it impossible to read the small less white lines in units beyond number ten (or even units below ten in very high contrast prints).

In reading low contrast prints with both light sources, we found the number of units resolved to be almost the same in both cases. However, on each low contrast prints read, the transmitted light from the viewing table gave a haze effect over the target, obscuring about one unit which was seen to be clearly resolved when read with reflected light, which is due to the fact that reflection contrast is twice as large as transmission contrast.

Following are the results of readings with both light sources using high and low contrast prints. These are averages of three readings.

B. Objective Comparison of Transmitted Light from Viewing Table and Reflected Light from Desk Lamp as Illumination on Resolution Targets.

HIGH CONTRAST PRINTS

No:	With Desk Lamp (res. l/mm)		At Viewer (res. l/mm)	
36	10.00	10.00	29.57	29.57
129	11.05	10.18	15.87	15.87
130	11.05	9.31	15.87	15.87
131	11.73	11.05	20.00	15.87
132	12.60	10.00	25.20	25.00
133	20.36	15.87	37.25	37.25
134	21.73	15.87	40.00	40.00
135	8.77	6.85	12.60	10.87
136	7.39	6.30	12.60	10.00
137	8.08	7.39	15.87	13.69
160) Medium	54.76	59.12	59.12	68.99
164) Contrast	54.76	54.76	63.49	63.49

LOW CONTRAST PRINTS

No:	With Desk Lamp		At Viewer	
49	46.93	50.39	40.00	40.00
99	40.00	40.00	37.25	37.25
100	43.46	50.39	40.00	40.00
101	34.50	37.25	25.20	25.20
107	34.50	37.25	25.20	25.20
111	40.00	40.00	34.50	40.00
112	50.39	50.39	31.75	35.00
113	31.75	31.75	20.00	23.47
116	31.75	31.75	20.00	15.87
175	50.39	50.39	40.00	40.00
176	43.46	50.39	31.75	40.00

C. The Effect of Filters On The Reading of Resolution.

It was considered that the possibility of reducing the glare of the white background in the contact prints might result in better resolution readings. The following is a summary of this theory.

1. Conditions and Results:
   a) Readings were made under conditions outlined in the conclusion, i.e. without a filter. Resolution readings: 79.99 l/mm
   b) Conditions as in conclusion but with Wratten filter No: CC34. Glare was cut down to some extent, making the reading a little more restful on the eyes. The amount of light absorbed by the filter was negligible. Resolution was between 63.49 and 79.99, the latter value not being as clearly visible as in case one. (a)
   c) Conditions as in conclusion but with Wratten filter No: CC44. In this case also, glare was cut down appreciably making it more restful on the eyes. The light however was also cut down, resulting in a lowered reading equal to 63.49 l/mm.
   d) Conditions as in conclusion but with Wratten filter No: 78AA. The glare in this case was again cut down considerably. The absorption of the light, however, was also cut down considerably, the result being a reading of 25.20 l/mm.
   e) The abover readings were made by three observers.
2. Conclusions:
   It has therefore been decided that though a filter would have value cutting down the glare of the light, and though, as in the case of filter No: CC34, the amount of light absorbed was negligible, still the

c. The Effect of Filters on the Resolving of Resolution.

It was considered that the possibility of reducing the glare of the white background in the contact prints might result in better resolution readings. The following is a summary of this theory.

1. Conditions and Results:

a) Readings were made under conditions outlined in the conclusion, i.e. without a filter. Resolution readings: 79.99 l/mm

b) Conditions as in conclusion out with Wratten filter No: CC34. Glare was cut down to some extent, making the reading a little more restful on the eyes. The amount of light absorbed by the filter was negligible. Resolution was between 63.49 and 79.99, the latter value not being so clearly visible as in case one. (a)

c) Conditions as in conclusion out with Wratten filter No: CC44. In this case also, glare was cut down appreciably making it more restful on the eyes. The light however was also cut down, resulting in a lowered reading equal to 50.79 l/mm.

d) Conditions as in conclusion but with Wratten filter No: YS44. The glare in this case was again cut down considerably. The absorption of the light, however, was also cut down considerably, the result being a reading of 25.20 l/mm.

e) The above readings were made by three observers.

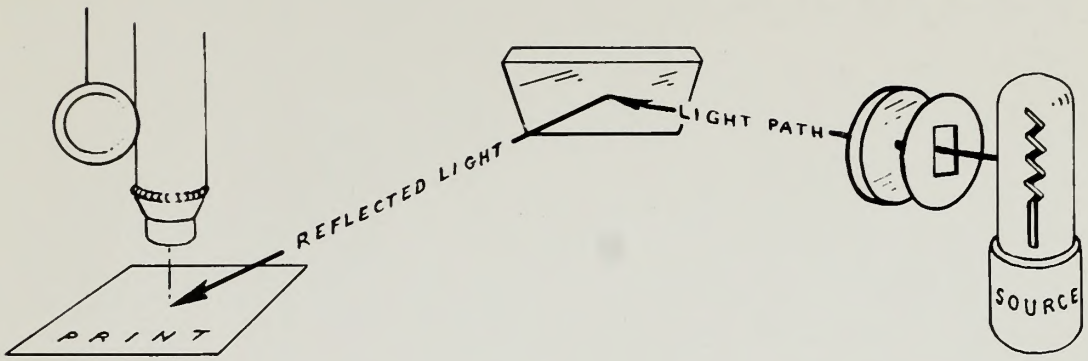
2. Conclusions:

It has therefore been decided that though a filter would have value cutting down the glare of the light, and though, as in the case of filter No: CC34, the amount of light absorbed was negligible, still the

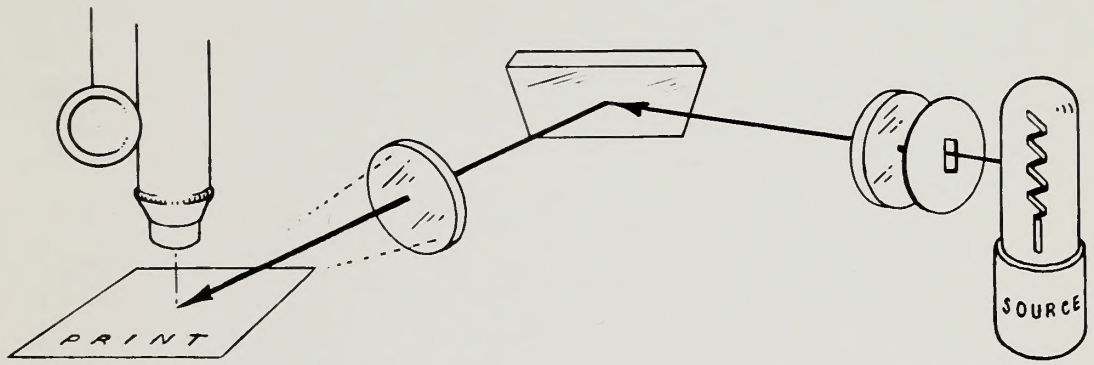
BASIC EQUIPMENT

LIGHT COLLECTION

LIGHT PROJECTION

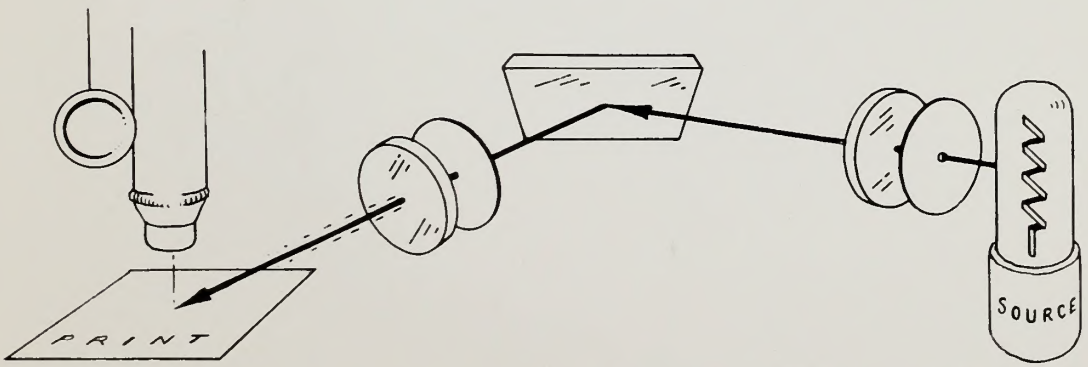


VARIATIONS



USE OF CONVEX LENS IN PATH OF REFLECTED LIGHT

DECREASE IN SLIT WIDTH



CONVEX LENS COVERED EXCEPT FOR $\frac{1}{32}$ APERTURE

SLIT REPLACED BY $\frac{1}{16}$ APERTURE

highest resolution obtained was without a filter, so that the resulting glare will be neglected.

D. Additional Investigation Into the Problem Has Been Made as Follows:

1. Reproduction of typical prints from Part B on Matte Paper
2. Prints of reproduction of original on matte and glossy (positive prints of white lines on black background.)
3. The following are the results.
   a) Matte Prints from Report II:

High Contrast	
Reflection	Transmission
20.00 l/mm	41.01 l/mm

Medium Contrast	
Reflection	Transmission
57.52 l/mm	52.50 l/mm

   b) Results of Prints From Reproduction:

(Glossy)

High Contrast	
Reflection	Transmission
5.00 l/mm	5.00 l/mm

Low Contrast	
Reflection	Transmission
10.92 l/mm	8.05 l/mm

(Matte)

Low Contrast	
Reflection	Transmission
8.59 l/mm	7.83 l/mm

highest resolution obtained was without a filter,
so that the resulting plate will be neglected.

b. Additional Investigation Into the Problem Has Been Made as Follows:

1. Reproduction of typical prints from Part 3 on Matte Paper

2. Prints of reproduction of original on matte and glossy (positive prints of white lines on black background.)

3. The following are the results.

a) Matte Prints from Report II:

High Contrast

Reflection	Transmission
20.00 l/mm	11.01 l/mm

Medium Contrast

Reflection	Transmission
57.52 l/mm	52.50 l/mm

b) Results of Prints From Reproduction:

(Glossy)

High Contrast

Reflection	Transmission
5.00 l/mm	5.00 l/mm

Low Contrast

Reflection	Transmission
10.92 l/mm	8.05 l/mm

(Matte)

Low Contrast

Reflection	Transmission
8.59 l/mm	7.83 l/mm

4. With this additional investigation the following conclusions are drawn:

   a) White lines on dark background do not compensate for the difference in readings.

   b) The low values of resolution from the reproduction (white lines on dark background) is directly attributed to the following phenomenon. When viewing these prints through a microscope with a magnification power of twenty times it is observable that focusing on the density square on target "B" sharply reproduces the surface grain of the paper which is now more visible because of the density deposit. Focusing on the density square results in the resolution pattern being out of focus. This effect is only observable in the case of matte prints. In all the cases of these readings, it was noted that the horizontal target immediately following the last one resolved tended to have the effect of being eclipsed, i.e., only a segment of the line was visible to the eye, whereas, in the case of the vertical half, all three lines were visible and resolved. The readings in every case show higher resolution in the vertical lines with the matte reproduction prints and approximately equal resolution between vertical and horizontal in the prints of the original target.

   c) With the elimination of all evident factors for explaining the variance of resolution readings by transmission and reflection, it

is recommended that possibly different criteria should be set up for determining resolution on paper.

E. Standardized Conditions:

Since the standard method of viewing prints for resolution is by reflection, this method will be used in this case with the following conditions:

1. Fluorescent desk lamp at an angle of approximately 45° and a distance no greater than two inches from the paper.
2. Magnification will be twenty times.
   a) Eyepiece = 10 times
   b) Objective = 2 times
3. Readings to be done in the afternoon and/or morning for no longer than one hour at a time.

BIBLIOGRAPHY

BRITISH REPORTS:

APRC-48
APRC-90
APRC-92
APRC-95
APRC-102
APRC-150
APRC-159
W-106-4
W-160-4
W-160-10
W-160-15
WA-854-16
II-5-3611
Ph-331
Ph-668

AMERICAN REPORTS:

Office of Scientific Research and Development Reports:

1. Report No: 4047
2. Report No: 4738

WRIGHT FIELD REPORTS:

1. Colton, E.,Capt. AC -"Variable Contrast Photographic Paper" ENG-59-680-22-16 (1943)
2. Colton, E.,Capt. AC -"Shrinkage Test of A Type IX Photographic Paper Suitable For Mosaics" ENG-59-680-22-17 (1944)
3. Kendall, C.W. -"Contact Printing - Loss of Print Detail Caused by Lack of Contact" EXP-M-59-680-4 (1942)
4. Kendall, C.W. -"The Mensural Properties of Photographic Films and Papers Used in Aerial Photography" TSEPL-4-680-66-5 (1945)
5. Levison, W.J. 2nd Lt.AC-"Resolving Power of Army Air Forces Chloride Papers" ENG-59-680-62-4
6. Levison, W.J. 2nd Lt.AC-"Resolving Power in Contact Printing" ENG-59-680-62-8

BIBLIOGRAPHY

BIBLIOGRAPHY (continued)

7. Motyer, L.N. Sgt.,AC -"Resolving Power of Photographic Paper"
TSEPL-4-680-62-16 (1945)

8. Phillips, C.H.2nd Lt. (AAF) -"Study of Variable Contrast Papers"
EXP-M-59-680-25-2 (1942)